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NUS Corp., Gaithersburg, MD

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Abstract: The report is one in a series of manuals dealing with air pathway analysis at hazardous waste sites. The document was developed for the Office of Air Quality Planning and Standards in cooperation with the Office of Emergency and Remedial Response (Superfund). The document is an interim final manual offering technical guidance for use by a diverse audience including EPA Air and Superfund Regional and Headquarters staff, State Air and Superfund program staff, Federal and State remedial and removal contractors, and potentially responsible parties in analyzing air pathways at hazardous waste sites. The manual provides for flexibility in tailoring the air pathway analysis to the specific conditions of each site, the relative risk posed by this and other pathways, and the program resource constraints.

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Volume IV - Procedures for Dispersion Modeling and Air Monitoring for Superfund Air Pathway Analysis

Interim Final

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PROCEDURES FOR CONDUCTING AIR PATHWAY ANALYSES FOR SUPERFUND APPLICATIONS

VOLUME IV

Procedures for Dispersion Modeling and Air Monitoring for Superfund Air Pathway Analysis

Interim Final

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PREFACE

This is one in a series of manuals dealing with air pathway analysis at hazardous waste sites. This document was developed for the Office of Air Quality Planning and Standards in cooperation with the Office of Emergency and Remedial Response (Superfund). It has been reviewed by the National Technical Guidance Study Technical Advisory Committee and an expanded review group consisting of State agencies, various groups within the U.S. Environmental Protection Agency, and the private sector. This document is an interim final manual offering technical guidance for use by a diverse audience including EPA Air and Superfund Regional and Headquarters staff, State Air and Superfund program staff, Federal and State remedial and removal contractors, and potentially responsible parties in analyzing air pathways at hazardous waste sites. This manual is written to serve the needs of individuals having different levels of scientific training and experience in designing, conducting, and reviewing air pathway analyses. Because assumptions and judgments are required in many parts of the analysis, the individuals conducting air pathway analyses need a strong technical background in air emission measurements, modeling, and monitoring. Remedial Project Managers, On Scene Coordinators, and the Regional Air program staff, supported by the technical expertise of their contractors, will use this guide when establishing data quality objectives and the appropriate scientific approach to air pathway analysis. This manual provides for flexibility in tailoring the air pathway analysis to the specific conditions of each site, the relative risk posed by this and other pathways, and the program resource constraints.

Air pathway analyses cannot be reduced to simple "cookbook" procedures. Therefore, the manual is designed to be flexible, allowing use of professional judgment. The procedures set out in this manual are intended solely for technical guidance. These procedures are not intended, nor can they be relied upon, to create rights substantive or procedural, enforceable by any party in litigation with the United States.

It is envisioned that this manual will be periodically updated to incorporate new data and information on air pathway analysis procedures. The Agency reserves the right to act at variance with these procedures and to change them as new information and technical tools become available on air pathway analyses without formal public notice. The Agency will, however, attempt to make any revised or updated manual available to those who currently have a copy through the registration form included with the manual.

Copies of this report are available, as supplies permit, through the Library Services Office (MD-35), U.S. Environmental Protection Agency, Research Triangle Park, North Carolina 27711 or from the National Technical Information Services, 5285 Port Royal Road, Springfield, Virginia 22161.

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APPENDIX C: BACKGROUND INFORMATION

SUPERFUND ABBREVIATIONS/ACRONYMS

ACGIH	American Conference of Government Industrial Hygienists
ACL	Alternate Concentration Limit
AO	Administrative Order on Consent
APA	Air Pathway Analysis
APCD	Air Pollution Control Device
ARAR	Applicable or Relevant and Appropriate Requirement (Cleanup Standard)
ATSDR	Agency for Toxic Substances and Disease Registry
CAA	Clean Air Act
CAS	Carbon Adsorption System
CD	Consent Decree
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CERCLIS	Comprehensive Environmental Response, Compensation, and Liability Information System
CERI	Center for Environmental Research Information
CFR	Code of Federal Regulations
CR	Community Relations
CRF	Combustion Research Facility -- Pine Bluff, Arkansas
CWA	Clean Water Act
DQO	Data Quality Objective
DRE	Destruction and Removal Efficiency
EDD	Enforcement Decision Document
ERT	Environmental Response Team
ESP	Electrostatic Precipitator
FIFRA	Federal Insecticide, Fungicide, and Rodenticide Act
FP	Fine Particualte

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FS	Feasibility Study
HRS	Hazard Ranking System
HSWA	Hazardous Waste Engineering Amendments to RCRA, 1984
HWERL	Hazardous Waste Engineering Research Laboratory
IDLH	Immediately Dangerous to Life or Health
MCL	Maximum Contaminant Level
MCLG	Maximum Contaminant Level Goal
NBAR	Non-binding Preliminary Allocation of Responsibility
NCP	National Contingency Plan
NEIC	National Enforcement Investigations Center
CFPA	National Fire Protection Association
NIOSH	National Institute of Occupational Safety and Health
NPL	National Priorities List
NRC	National Response Center
NRT	National Response Team
NTIS	National Technical Information Service
OERR	Office of Emergency and Remedial Response
O&M	Operation and Maintenance
ORD	Office of Research and Development
OSC	On-Scene Coordinator
OSH Act	Occupational Safety and Health Act
OSHA	Occupational Safety and Health Administration
OSWER	Office of Solid Waste and Emergency Repsonse
OTA	Office of Technology Assessment
PA	Preliminary Assessment
PEL	Permissible Exposure Limits

PIC	Products of Incomplete Combustion
PM-20	Particualte Matter with Physical Diameter <20 um
PRP	Potentially Responsible Party
QA/QC	Quality Assurance/Quality Control
QAPP	Quality Assurance Project Plan
RA	Remedial Action
RCRA	Resource Conversation and Recovery Act
RD	Remedial Design
REL	Recommended Exposure Limit
RI	Remedial Investigation
RI/FS	Remedial Investigation/Feasibility Study
ROD	Record of Decision
RPM	Remedial Project Manager
RRT	Regional Response Team
RQ	Reportable Quantity
SAB	Science Advisory Board
SARA	Superfund Amendments and Reauthorization Act
SCAP	Superfund Comprehensive Accomplishments Plan
SI	Site Inspection
SITE	Superfund Innovative Technology Evaluation
SWDA	Solid Waste Disposal Act (RCRA predecessor)
TLV	Threshold Limit Value
TLV-C	Threshold Limit Value - Ceiling
TLV-STEL	Threshold Limit Value - Short-Term Exposure Limit
TLV-TWA	Threshold Limit Value - Time-Weighted Average
TSDF	Treatment Storage and Disposal Facility
TSCA	Toxic Substances Control Act

TSP	Total Suspended Particulate
Title III	Emergency Planning and Community Right-To-Know Act (SARA)
T&E	Testing and Evaluation
UST	Underground Storage Tank
VO	Volatile Organics
VOC	Volatile Organic Compound

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SECTION 1
INTRODUCTION

The multivolume set of Procedures for Conducting Air Pathway Analyses for Superfund Applications has been developed in response to increased concern by the U.S. Environmental Protection Agency (EPA) regarding the potential for hazardous air emissions from Superfund sites. These emissions can occur at hazardous spill locations and undisturbed Superfund sites, as well as during site cleanups. Under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) and the recent Superfund Amendments and Reauthorization Act (SARA), EPA has the responsibility for assessment and cleanup of these Superfund sites. Although air emissions pose a potential human health risk from air emissions at these sites, comprehensive national guidance did not exist for determining the magnitude and impact of these emissions. Therefore, the goal of these Procedures is to provide technical recommendations for the conduct of air pathway analyses (APAs) that meet the needs of the Superfund process, presenting alternative technical approaches for the conduct of APAs and providing recommendations for preferred or default approaches. The Procedures are intended for use by EPA Remedial Project Managers (RPMs), Enforcement Project Managers (EPMs), and air experts, as well as by EPA Superfund contractors. The procedures are also generally applicable to hazardous waste sites not included on the NPL.

The Procedures for Conducting Air Pathway Analyses for Superfund Applications consists of four volumes:

- Volume I - Application of Air Pathway Analyses for Superfund Activities

- Volume II - Estimation of Baseline Emissions at Superfund Sites

- Volume III - Estimation of Air Emissions from Cleanup Activities at Superfund Sites

- Volume IV - Procedures for Dispersion Modeling and Air Monitoring for Superfund Air Pathway Analyses.

Volume I defines the general approach for the conduct of APAs and references appropriate sections within Volumes II-IV for detailed technical procedures regarding modeling and monitoring techniques. Volume II provides procedures for developing baseline air emission estimates, and Volume III provides procedures for estimating air emission impacts from remedial actions. Specifically, Volumes II-IV present alternative and preferred or default modeling techniques and monitoring techniques for implementing the APA approaches selected based on Volume I recommendations. This information will be primarily of interest to EPA air experts and Superfund contractors responsible for the conduct of APAs. However, the technical procedures provided in Volumes II-IV are not specific to Superfund activities. Therefore, Volumes II-IV will also be useful to state air staff responsible for supporting hazardous waste site cleanup.

The emphasis of Volume IV is on providing technical procedures for dispersion modeling and air monitoring. Volume IV provides the procedures for implementing activity-specific and source-specific dispersion modeling/air monitoring recommendations provided in Volume I. Volumes II and III also cross-reference Volume IV for certain air emission characterization approaches that require the conduct of dispersion modeling and/or air monitoring. In addition, implementation of Volume IV procedures frequently requires source emission rate inputs that can be developed through application of Volumes II and III.

Section 2 of this volume presents procedures for the application of atmospheric dispersion modeling as a methodology to assess potential exposures associated with air emissions from a Superfund site. This material will include criteria as well as recommendations for selecting models, obtaining required input data, and interpreting modeling results. These procedures address technical issues that are significant for Superfund applications. Therefore, the procedures presented in Section 2 should be considered as supplemental to, but not replacements for, the Guideline On Air Quality Models (U.S. EPA, 1986).

Section 3 presents procedures for the application of air monitoring to characterize downwind exposure conditions from Superfund air emission sources. These procedures discuss the technical challenges involved in the design and implementation of an air toxic monitoring program. Again, the emphasis has been on providing recommendations specific to conducting Superfund APAs. Therefore, available standard procedures for conducting air toxic monitoring programs are identified and summarized. However, the material has also been adapted and supplemented as necessary to address Superfund applications.

The technical procedures presented in Volumes II-IV are based on the general format illustrated in Figure 1 and discussed in Volume I. The major elements of these procedures are as follows:

- Collect and review APA input information
- Select APA sophistication level
- Develop APA plan
- Conduct APA
- Summarize/evaluate results
- Evaluate need for additional analyses.

Data quality objectives (DQOs) should be considered during each step. The following is a brief discussion of each of these procedural steps.

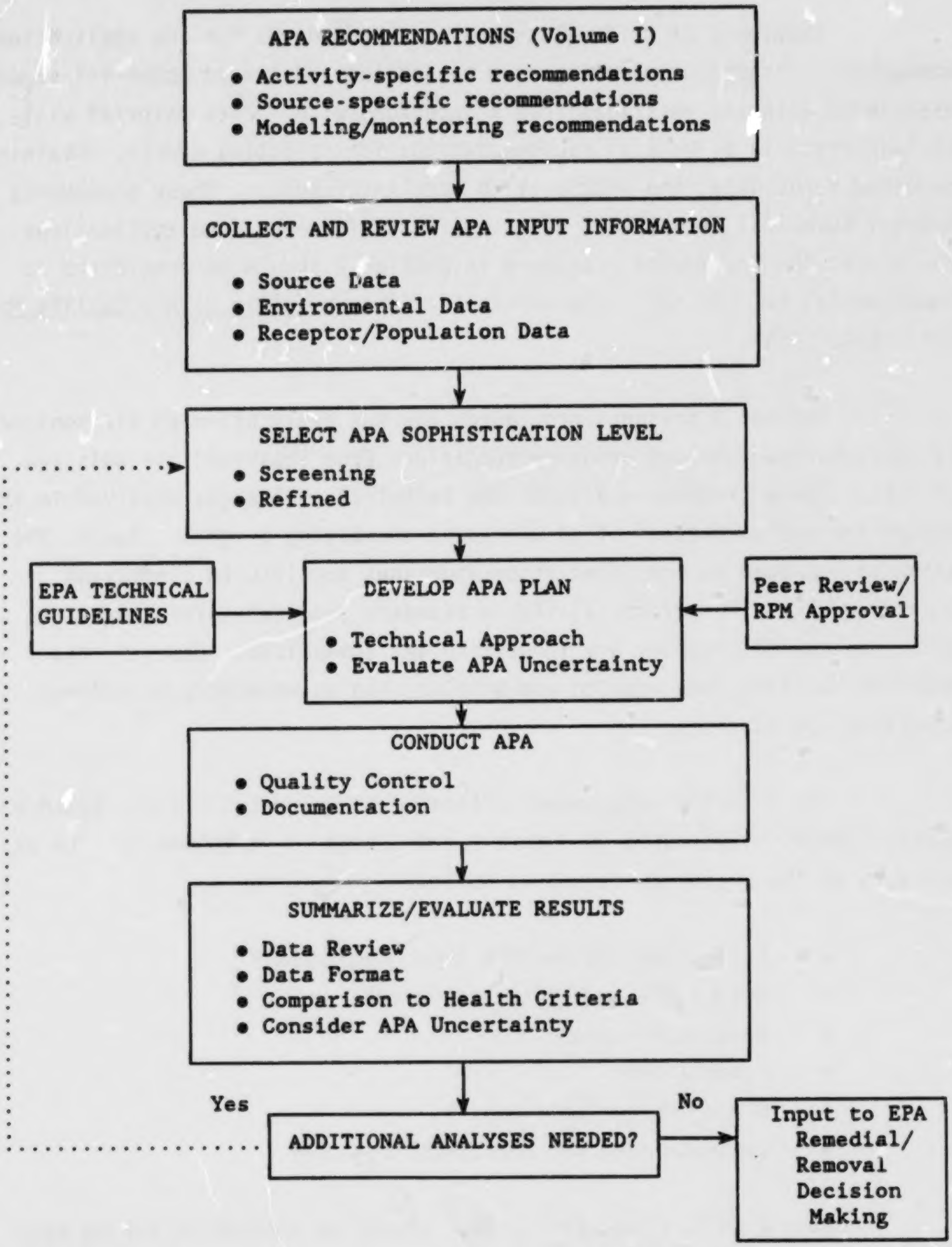
APA RECOMMENDATIONS (Volume I)
• Activity-specific recommendations
• Source-specific recommendations
• Modeling/monitoring recommendations
COLLECT AND REVIEW APA INPUT INFORMATION
• Source Data
• Environmental Data
• Receptor/Population Data
SELECT APA SOPHISTICATION LEVEL
• Screening
• Refined
EPA TECHNICAL GUIDELINES
DEVELOP APA PLAN
• Technical Approach
• Evaluate APA Uncertainty
Peer Review/ RPM Approval
CONDUCT APA
• Quality Control
• Documentation
SUMMARIZE/EVALUATE RESULTS
• Data Review
• Data Format
• Comparison to Health Criteria
• Consider APA Uncertainty
Yes
No
ADDITIONAL ANALYSES NEEDED?
Input to EPA Remedial/ Removal Decision Making

Figure 1. Superfund Air Pathway Analyses Technical Procedures - General Format.

Step 1 - Collect and Review Input Information--This initial step addresses the process of collecting and compiling existing information pertinent to previous site-specific APAs based on a literature survey. It includes obtaining available source, receptor, and environmental data. Once the existing data have been collected, compiled, and evaluated, data gaps can be defined and a coherent monitoring plan or modeling plan developed based on the site-specific requirements.

Step 2 - Select APA Sophistication Level--This step involves the selection of the APA sophistication level considering screening versus refined monitoring and modeling techniques. This selection process depends on program objectives as well as available resource and technical constraints. Technical aspects that should be considered include the availability of appropriate monitoring and modeling techniques.

Step 3 - Develop APA Plan--This step involves preparation of an APA plan. The APA should include documentation of the selected technical approach (e.g., nonrepresentative input data, modeling inaccuracies and monitoring limitations). The application of Data Quality Objectives (DQOs) will be an important aspect in the development of an APA plan. The selected approach should be based on EPA technical guidelines, as available. The APA plan also facilitates peer review of the technical approach and a formal process for approval of the APA by the RPM/EPM. The peer review process may involve EPA air experts or contractor support.

Step 4 - Conduct APA--This step involves the implementation of the APA plan developed during Step 3. The emphasis during Step 4 is on conducting the APA commensurate with appropriate QC measures and DQO criteria. This also involves documentation of the APA process (to facilitate the QC process and establish an information base that may be useful for APAs at other Superfund sites).

Step 5 - Summarize and Evaluate Results--This step involves reviewing data and evaluating APA results for validity. Additional components of this step should include (a) data processing; (b) preparation of statistical summaries; (c) comparison of upwind and downwind concentration results; and (d) concentration mapping, if possible. Estimates of data uncertainties based on instrument limitations and analytical technique inaccuracies should also be obtained and used to qualify air monitoring results. Results can be compared to applicable or relevant and appropriate (ARAR) air criteria and other Superfund health and safety criteria. The results of Step 5 can also provide input to the Superfund risk assessment process.

This approach ensures that a common thought process and strategy are used to plan and conduct APAs for Superfund application. As demonstrated in Sections 2-3, this general approach has been adapted for each of the technical procedures presented in Volume IV.

SECTION 2
ATMOSPHERIC DISPERSION MODELING PROCEDURE

2.1 OVERVIEW

Atmospheric dispersion modeling is an air pathway analysis (APA) approach that can provide calculated contaminant concentrations at receptor locations of interest based on emission rate and meteorological data. Atmospheric dispersion modeling for Superfund activities is an integral part of the planning and decision-making process for the protection of public health and the environment. Dispersion modeling results may be useful at all stages of the Superfund process and are especially necessary for predicting impacts from proposed remedial actions. This section provides procedures for the selection and application of dispersion modeling approaches for Superfund APAs.

The two major dispersion modeling applications for Superfund are:

- To estimate concentrations at receptors of interest using input emission rate data based on field measurements or emission model predictions; and

- To design an air monitoring program (i.e. selecting monitoring locations and periods) as well as in interpreting and extrapolating monitoring results.

Atmospheric dispersion models can be used when designing an air monitoring program to see how offsite areas of high concentration relate to actual receptor locations. Places where high-concentration areas correspond to actual receptors are priority locations for air monitoring stations.

Dispersion models can also be used to provide seasonal dispersion concentration patterns based on available representative historical meteorological data (either onsite or offsite). These dispersion patterns can be used to evaluate the representativeness of any air monitoring data collection period. Data representativeness is determined by comparing the dispersion concentration patterns for the air monitoring period with historical seasonal dispersion concentration patterns.

It is often not practical to place air monitoring stations at actual offsite receptor locations of interest. It will be necessary, however, to characterize concentrations at these locations to conduct a health and environmental assessment. In these cases, dispersion patterns based on modeling results can be used to extrapolate concentrations monitored at the Superfund site to offsite receptor locations.

A summary of Superfund APA dispersion modeling recommendations and objectives is presented in Table 1. These recommendations are presented as a function of source classification and Superfund activities. Emission rate inputs for dispersion modeling applications should be based on technical procedures presented in Volumes II and III. Meteorological modeling input data should preferably be based on an onsite monitoring program. (See Sections 2.2. and 3.4.3 of this volume). The preferred dispersion model for Superfund APA applications is the Industrial Source Complex (ISC) model. This model can be used for estimating short-term concentrations (i.e., the ISCST version) and long-term concentrations (i.e., ISCLT version) for a variety of Superfund sources. Further discussions of dispersion model selection are included in Sections 2.3 and 2.4. It is also recommended that near real-time concentration estimates associated with nonroutine air releases be developed, as necessary. A combination of monitoring/modeling approaches is recommended to provide this capability. An example of this approach is provided in Appendix C.

TABLE 1. SUMMARY OF DISPERSION MODELING RECOMMENDATIONS AND OBJECTIVES

Source Classification	Dispersion Modeling Objectives	APA Recommendations	Superfund Activities
Pre-Remediation Source	• Provide sufficient data base on concentrations of air toxic contaminants for performing a detailed risk assessment of public health and the environment for on-site, perimeter and off-site receptors for the baseline conditions (no-action alternative). • Provide sufficient data base on concentrations of air toxic contaminants for performing a detailed risk assessment of public health and the environment for on-site, perimeter and off-site receptors for the various remedial alternatives. • Provide input to the design of air monitoring program step.	Characterize baseline air concentration: - Obtain emission rate estimates based on procedures presented in Volumes II and III. - Obtain meteorological input data based on an on-site monitoring program pursuant to recommendations presented in Volume IV - Section 3.4.3. - Conduct dispersion modeling based on considering ISC as the preferred model for Superfund APA applications.	RI/FS - Screening/ refined APA.

(Continued)

TABLE 1. (Continued)

Source Classification	Dispersion Modeling Objectives	APA Recommendations	Superfund Activities
Remediation source	• Provide air quality data to assess the affects of the remedial action evaluated. • Provide input to the design of air monitoring program for this step.	Characterize air concentrations during remedial/removal activities: - Obtain emission rate estimates based on procedures presented in Volumes II and III. - Obtain meteorological input data based on an on-site monitoring program pursuant to recommendations presented in Volume IV - Section 3.4.3. - Conduct dispersion modeling based on considering ISC as the preferred model for Superfund APA applications.	Remedial design (pilot field studies)

(Continued)

TABLE 1. (Continued)

Source Classification	Dispersion Modeling Objectives	APA Recommendations	Superfund Activities
Remediation source	• Provide input to the design of air monitoring program for this step. • Provide data on calculated concentrations of air toxic contaminants for routine and non-routine releases in support of protecting workers, the public, and the environment. • Provide data as a component of the emergency response system employed at the site to be used together with measured concentrations. • Provide calculated concentration data in support of protective actions during the remedial action activities.	Characterize air concentrations during remedial/removal activities: - Obtain emission rate estimates based on procedures presented in Volumes II and III. - Obtain meteorological input data based on an on-site monitoring program pursuant to recommendations presented in Volume IV - Section 3.4.3. - Conduct dispersion modeling based on considering ISC as the preferred model for Superfund APA applications. - Develop/implement a site-specific APA emergency field guide based on a combined monitoring/modeling approach to obtain near realtime dispersion estimates (see example in Appendix C).	Remedial actions (full-scale operations)

(Continued)

TABLE 1. (Continued)

Source Classification	Dispersion Modeling Objectives	APA Recommendations	Superfund Activities
Post-Remediation Source	• Provide air quality data base at the site perimeter and off-site as a part of assessing the effectiveness of the remedial action implemented. • Provide air quality data base at the site perimeter and off-site to demonstrate the protection of public health and the environment.	Confirm controlled source air concentrations: - Obtain emission rate estimates based on procedures presented in Volumes II and III. - Obtain meteorological input data based on an on-site monitoring program pursuant to recommendations presented in Volume IV - Section 3.0. - Conduct dispersion modeling based on considering ISC as the preferred model for Superfund APA applications.	Operation and maintenance (post-remedial activities)

Atmospheric dispersion modeling for Superfund activities includes a mix of sources that, in general, are different in configuration and characteristics from the sources traditionally modeled for air permitting applications. The traditional sources modeled for air permitting applications are usually elevated, buoyant, point sources (e.g., stacks) emitting combustion products such as sulfur dioxide, nitrogen oxides, carbon dioxide, and particulate matter. In contrast, the Superfund activities include mainly fugitive- area, volume, and line sources, and, to a small extent, point sources. A list of the types of sources associated with the various Superfund activities is presented in Table 2.

Superfund-area sources generally include landfills, lagoons, contaminated soil surfaces, and solidification/stabilization operations. Volume sources include structures within processing facilities, tanks, and containers. Line sources include paved and unpaved roads, and point sources include air strippers, incinerators, and in situ venting operations. Most Superfund sources are considered ground-level or near-ground-level, nonbuoyant releases.

Superfund activity emissions exhibit more involved and complex processes that govern the rate and type of air emissions compared with air emissions from traditionally modeled sources. Air emissions from Superfund activities can be continuous or intermittent releases, or a one-time release over a defined period of time. The releases can be routine or unforeseen. Both gaseous and particulate matter emissions must be considered. The gaseous emissions include volatile and semivolatile compounds, and particulate matter emissions include semivolatile, base neutrals, metals and other inorganic compounds. Table 1 lists the general type of gaseous and particulate matter emissions associated with various Superfund activity sources as well as the anticipated nature of the release.

TABLE 2. SOURCES ASSOCIATED WITH SUPERFUND ACTIVITIES AND THEIR CHARACTERISTICS

		Important Air Emission Mechanisms		Emission Mode		
Superfund Source	Source[a] Configuration	Gas Phase	Particulate Phase	Gas Phase	Particulate Phase	Routine/ Non-Routine Release
Pre-remediation Sources:						
• Landfills	Fugitive Area	Volatilization, biodegradation	Wind Erosion, mechanical disturbances	Continuous	Intermittent	Routine
• Lagoons	Fugitive Area	Volatilization, biodegradation	Wind Erosion, mechanical disturbances	Continuous	Intermittent	Routine
• Contaminated soil surfaces	Fugitive Area	Volatilization, biodegradation	Wind Erosion mechanical disturbances	Continuous	Intermittent	Routine
• Containers	Fugitive Area volume	Volatilization, biodegradation	Mechanical diturbances	Continuous	Intermittent	Routine
• Process Facilities	Fugitive Area volume line, point	Volatilization, combustion	Wind Erosion, mechanical disturbances	Continuous	Intermittent	Routine
• Storage Tanks	Fugitive Area	Volatilization	--	Continuous	--	Routine
Remediation Sources:						
• Soil Handling	Fugitive Area, volume	Volatilization	Wind Erosion, mechanical disturbances	Continuous, Intermittent	Intermittent	Routine/ Non-Routine
• Air Stripper[b]	Point, Volume	Volatilization	Combustion	Continuous, Intermittent	Continuous	Routine/ Non-Routine
• Incinerator[b]	Point, Volume	Combustion	Combustion	Continuous, Intermittent	Continuous	Routine/ Non-Routine

(Continued)

TABLE 2. (Continued)

Superfund Source	Source[a] Configuration	Important Air Emission Mechanisms		Emission Mode		Routine/ Non-Routine Release
		Gas Phase	Particulate Phase	Gas Phase	Particulate Phase	
Remediation Sources: (Continued)						
• In-situ Venting	Fugitive Area	Volatilization	--	Continuous Intermittent	--	Routine/ Non-Routine
• Solidification/ Stabilization	Fugitive Area, volume	Volatilization	Wind Erosion, mechanical disturbances	Continuous, Intermittent	Intermittent	Routine/ Non-Routine
Post-remediation Sources:						
• Landfills	Fugitive Area	Volatilization, biodegradation	Wind Erosion, mechanical disturbances	Continuous	Intermittent	Routine
• Lagoons	Fugitive Area	Volatilization, biodegradation	Wind Erosion, mechanical disturbances	Continuous	Intermittent	Routine
• Soil Surfaces	Fugitive Area	Volatilization, biodegradation	Wind Erosion, mechanical disturbances	Continuous	Intermittent	Routine
• Containers	Fugitive Area volume	Volatilization, biodegradation	Mechanical disturbances	Continuous	Intermittent	Routine

[a] Most Superfund sources are ground level or near ground level non-buoyant releases.

[b] Small stacks where plume is frequently in the downwash cavity.

The factors discussed above clearly imply that many of the currently employed air dispersion models for traditional sources, as outlined in the U.S. Environmental Protection Agency's Guidelines on Air Quality Models (Revised) (EPA-450/2-78-027R, July 1986), have very little application to the Superfund APA. Only a limited number of models in the EPA Guidelines are applicable to Superfund applications. It is therefore important to define the sources involved, their configuration, and their characteristics before a suitable model is selected.

It can also be concluded that the added complexity of air dispersion modeling for Superfund activities is mainly associated with estimating emission rates for the specific source under consideration. It is therefore vital to develop emission inventory data for the sources involved based on the procedures outlined in Volumes II and III of this series for pre-remediation sources, remediation sources, and post-remediation sources. It is also critical to subdivide large-area sources to smaller sources in accordance with the guidelines provided in this section to provide for a reasonably accurate simulation of air releases, transport, and dispersion. Although some of the emissions from Superfund activities include reactive constituents, they are handled in this section as passive constituents. This is a reasonable approximation because the source-receptor distances involved do not exceed 10 to 15 kilometers and the plume travel time for these distances ranges from less than 1 hour to 1 or 2 hours.

The various technical factors discussed above will be further elaborated on in Sections 2.2 through 2.6.

The procedures for atmospheric dispersion modeling presented in this section are based on a five-step process (illustrated in Figure 2):

- Step 1 - Collect and review input information;
- Step 2 - Select modeling sophistication level;
- Step 3 - Develop modeling plan;
- Step 4 - Conduct modeling; and
- Step 5 - Summarize and evaluate results.

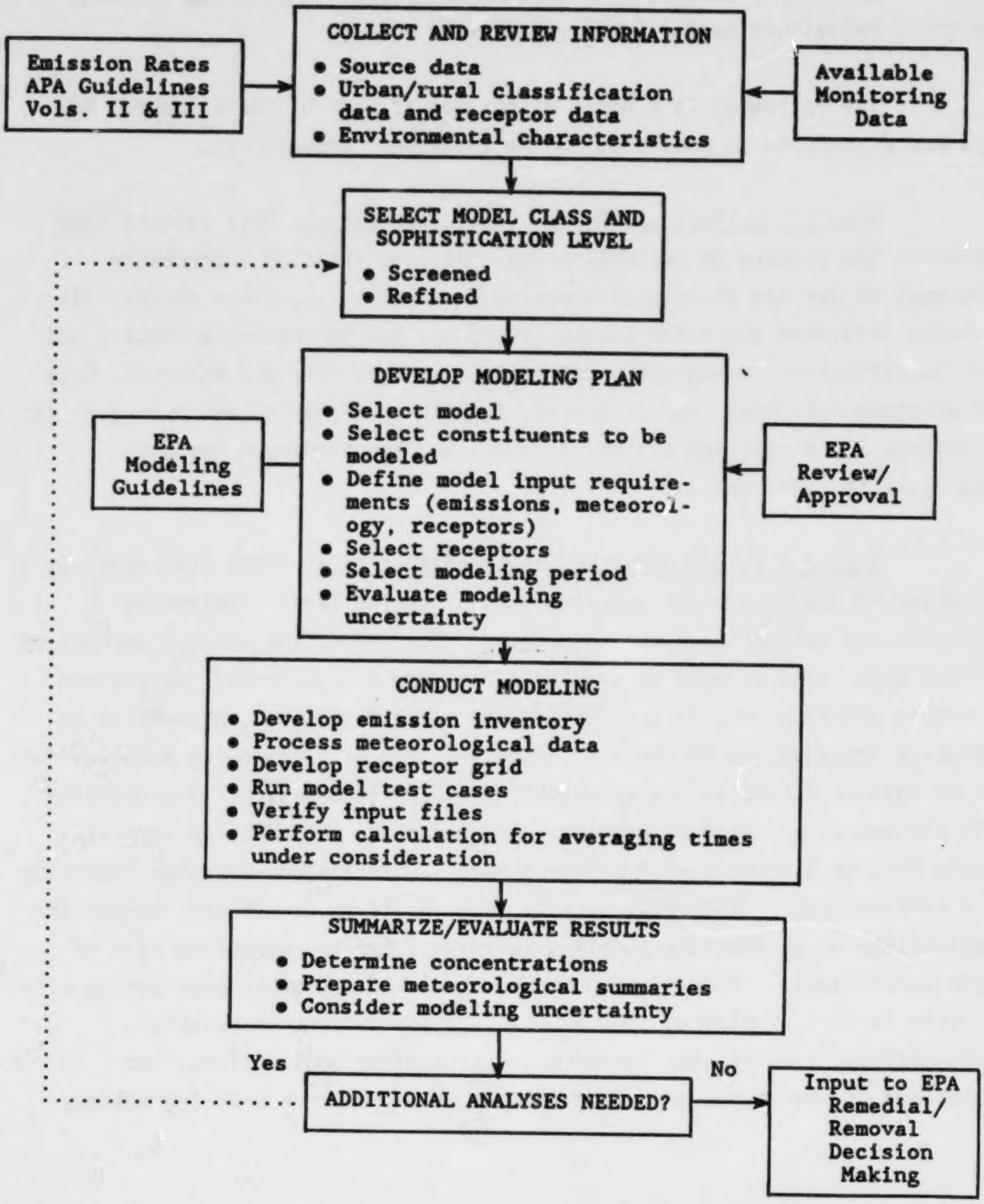
Emission Rates
APA Guidelines
Vols. II & III
COLLECT AND REVIEW INFORMATION
• Source data
• Urban/rural classification data and receptor data
• Environmental characteristics
Available Monitoring Data
SELECT MODEL CLASS AND SOPHISTICATION LEVEL
• Screened
• Refined
EPA Modeling Guidelines
DEVELOP MODELING PLAN
• Select model
• Select constituents to be modeled
• Define model input requirements (emissions, meteorology, receptors)
• Select receptors
• Select modeling period
• Evaluate modeling uncertainty
EPA Review/ Approval
CONDUCT MODELING
• Develop emission inventory
• Process meteorological data
• Develop receptor grid
• Run model test cases
• Verify input files
• Perform calculation for averaging times under consideration
SUMMARIZE/EVALUATE RESULTS
• Determine concentrations
• Prepare meteorological summaries
• Consider modeling uncertainty
Yes
ADDITIONAL ANALYSES NEEDED?
No
Input to EPA Remedial/ Removal Decision Making

Figure 2. Superfund Air Pathway Analyses Dispersion Modeling Protocol

Additional technical discussion on dispersion modeling is found in the EPA's Guidelines on Air Quality Models.

The following is a brief discussion of each of these steps. An expanded discussion is presented in the subsequent subsections.

Step 1 - Collect and Review Input Information--This initial step addresses the process of collecting and compiling existing information pertinent to the air dispersion modeling based on a literature survey. It includes obtaining available source, receptor, and environmental data (land use classification, demography, topography, meteorology, and others). Once the existing data have been collected, compiled, and evaluated, data gaps can be defined and a coherent dispersion modeling plan developed based on site-specific requirements.

Step 2 - Select Modeling Sophistication Level--This step involves selection of the dispersion modeling sophistication level considering screening and refined modeling techniques. This selection process depends on program objectives as well as available resource and technical constraints. Screening models generally use limited and simplified input information to produce a conservative estimate of exposure. Use of a screening model allows for an initial determination of whether the Superfund site or site activity will present an air pathway problem. If warranted, the emission sources should then be evaluated with either a more sophisticated screening technique or a refined model. Technical aspects that should be considered include the availability of appropriate modeling techniques for the Superfund list of toxic constituents. Modeling approaches should be evaluated considering site specific factors, including source configuration and characteristics, applicability, limitations, performance for similar applications, and comparison of advantages and disadvantages of alternative modeling methods.

Step 3 - Develop Modeling Plan--This step involves preparation of a dispersion modeling plan. Elements that should be addressed in the plan include (a) overview of the Superfund site area, (b) selection of constituents to be modeled, (c) modeling methodology (emission inventory, meteorology, receptor grid, rural/urban classification, models to be used, concentration averaging time, and special situations such as wake effects), and (d) documentation of the air modeling plan.

Step 4 - Conduct Modeling--This step involves the actual activities of conducting air dispersion modeling for a Superfund site. It includes the following: (a) develop emission inventory, (b) preprocess and verify model input data (emission inventory, meteorology, receptor grid, and others), (c) set model switches, (d) run model test cases, (e) perform dispersion calculations, and (f) obtain printout of modeling input and output.

Step 5 - Summarize and Evaluate Results--This step involves reviewing and assessing the dispersion modeling results. Additional components of this step should include (a) preparation of data summaries, (b) concentration mapping (isopleths), (c) estimation of uncertainties, and (d) assessment.

2.2 STEP 1 - COLLECT AND REVIEW INPUT INFORMATION

2.2.1 Overview

The following information, at a minimum, should be collected and reviewed to support the air modeling program design:

- Source data;
- Receptor data; and
- Environmental data.

This type of information serves a dual purpose: 1) it provides an overall understanding of site-specific features that can affect dispersion modeling, and 2) it provides the necessary input to drive the dispersion model. The accuracy of the model predictions depends, of course, on the accuracy and representativeness of the input data.

Most of the site-specific information required for Step 1 is available from the Superfund Remedial Project Manager/Enforcement Project Manager (RPM/EPM). The quality of available information will depend on the nature and extent of the previously performed studies, but it should generally improve as the Superfund process progresses. In any event, available information and data should be evaluated for the following factors:

- Data quality objectives (DQO);
- Technical soundness of methodologies employed;
- Completeness and quality of the data;
- Quality assurance/quality control (QA/QC);
- Compatibility, representativeness, and applicability of the data; and
- Data gaps.

Supplemental information can be gathered through a literature search of records and documents from sources such as the following:

- National Weather Service;
- U.S. Environmental Protection Agency;
- State and local agencies;
- Contractor studies; and
- Other Federal government offices.

The information collected during Step 1 should be evaluated and the results documented using a form similar to the example presented in Table 3. In addition, copies of data summaries should be attached to the form to provide a convenient, complete documentation package for the project files.

TABLE 3. EXAMPLE - SUPERFUND AIR DISPERSION MODELING INPUT INFORMATION FORM

	Data Obtained		Evaluation Factors					
Data Type	(Yes or No or N/A)	(Attachment #)	Technical Methods Employed Acceptable (Yes or No)	Completeness and Quality of Data Acceptable (Yes or No)	QA/QC Appropriate (Yes or No)	Data Relevant for this Application (Yes or No)	Data Gaps Significant (Yes or No)	Comments
Source Data								
• Site Layout Map								
• Contaminants List								
• Emission Inventory								
• Contaminant Toxicity Factors								
• Off-Site Sources								
Receptor Data:								
• Population Distribution Map								
• Identification of Sensitive Receptors								
• Site Work Zones Map								
• Local Land Use								
Environmental Data:								
• Dispersion Data								
- Wind Direction/ Wind Speed								
- Atmospheric Stability								
• Climatology								
- Temperature - Humidity - Precipitation								
• Topographic Maps								
- Site - Local Area								
• Soil and Vegetation								

(Continued)

TABLE 3. (Continued)

	Data Obtained		Evaluation Factors					
Data Type	(Yes or No or N/A)	(Attachment #)	Technical Methods Employed Acceptable (Yes or No)	Completeness and Quality of Data Acceptable (Yes or No)	QA/QC Appropriate (Yes or No)	Data Relevant for this Application (Yes or No)	Data Gaps Significant (Yes or No)	Comments
Previous APA Data:								
• Emission Rate Modeling								
• Emission Rate Monitoring								
• Dispersion Modeling								
• Air Monitoring								
• ARAR Summary								

The following subsections provide a further discussion of the various types of data that should be collected during Step 1.

2.2.2 Source Data

Site-specific information on the nature and extent of the contamination is critical for estimating the magnitude of air emissions from each of the sources and in defining the primary emitted species. In addition, information on source configuration is vital. As discussed in Section 2.1 and summarized in Table 1, area sources constitute the majority of sources at a typical Superfund site. In general, the areas involved range from small (e.g., a fraction of an acre) to large (tens of acres), and their division by source characteristics and size can be critical to the success of this modeling analysis. The data should be available from the Superfund RPM/EPM. Specific information that should be collected, evaluated, and prepared as input into the dispersion model includes:

- Number and type of sources at the site and their locations based on past site activities and information on the extent of contamination. (Example sources are lagoons, drainage ditches, landfills, processing facilities, incinerators, air strippers, and roads.) The temporal and spatial variability of these sources should also be addressed. Source variability is an extremely important consideration for Superfund APAs. In particular, emission/source conditions during remediation can vary significantly.

- Configuration and classification (based on information presented in Table 2 and site-specific considerations) of sources as area, volume, line, or point sources.

- Dimensions of each area, volume, and line source, including the shape of sources (e.g., is the area source a rectangle, triangle, or other shape, does the line source constitute a straight or curved line) and the portions of a line source that do not have emissions. Nonsquare-area sources have to be approximated by a square for use in the dispersion model. If the square covers a large area, it may be advisable to subdivide it into smaller squares if calculated concentrations are required at short distances from the source. Similarly nonregular-volume sources have to be approximated by a cube and nonregular-shaped-line sources have to be approximated by minimizing the curvatures involved.

- Stack parameters, including stack height, exit diameter, exit velocity, and exit temperature for point sources.

- Contaminants associated with each source area. It will be useful to subdivide the contaminants into groups and subgroups with similar chemical or physical characteristics: organics (volatiles, semivolatiles, base neutrals, pesticides, polychlorinated biphenyls (PCBs)), and inorganics (metals and other toxic compounds [H_2S, HCN, etc]).

- Physical and chemical characteristics of the contaminants involved, including density relative to air (for gaseous emissions) and particle size distribution (for particulate matter emissions).

- Estimated typical long-term emission rates and typical as well as maximum short-term emission rates for each source under consideration. The emphasis for Superfund APAs is to define, as practical, realistic source input data for dispersion modeling purposes. For Superfund APA applications, the uncertainties associated with the input data as well as the accuracy of the dispersion model are considered during the data evaluation stage. This is different from air quality permitting applications for traditional sources, which are generally based on conservative source emission assumptions. The methods to estimate emission rates for various undisturbed and disturbed sources at a Superfund site are presented in Volume II and III, repectively, of this document.

Table 4 represents an example of input requirements for various source categories. As noted in Section 2.1, in contrast to conventional air emission sources that are considered mainly as point sources, Superfund sources consist mainly of area, volume, and line sources. Only a limited number of cases include point sources, mainly during remedial cleanup activities. It is therefore important to define the source configuration and to best approximate its shape to the shape acceptable by the employed dispersion model.

2.2.3 Receptor Data

Receptor data that correspond to data used for the Superfund risk assessment process should be identified. These data will provide the basis for specifying a calculational (receptor) grid for Superfund APA dispersion modeling application.

Specific receptor information that should be collected and evaluated before the selection of the receptor grid includes the following:

- Population distribution by 22.5-degree sectors in 2-kilometer increments for a distance of 10 kilometers from the site if total risk is to be considered;

- Sensitive receptors within 10 kilometers of the site and individual residences and buildings within 1 kilometer of the site;

TABLE 4. EXAMPLE OF INPUT REQUIREMENTS FOR VARIOUS SOURCE CATEGORIES

Input Parameter	Source Category			
	Point	Line	Area	Volume
Source Location	Coordinates of the point (m).	Coordinates of the center of the line (m).	Coordinates of the southwest corner of the area approximated by a square (m).	Coordinates of the center of the source (m).
Source Dimension	Stack height (m), exit diameter (m), exit velocity (m/sec), exit temperature (°K)	Length (m), Width (m), Height (m).	Width of the square area source (m).	Height of the volume source (m), width (m).
Source Emission Rate for each constituent under consideration.	Mass per unit time.	Mass per unit time per unit length, or mass per unit time if simulated by an array of volume sources.	Mass per unit time per unit area.	Mass per unit time.
Adjacent Obstructions	Height (m), Width (m), Length (m).	---	---	---
Initial Dilution	---	Initial horizontal and vertical dimensions (m).	Initial horizontal and vertical dimensions (m).	Initial horizontal and vertical dimensions (m).
Particle mass-size distribution and deposition velocity.	Fraction of mass in each size group. Average deposition velocity for each mass size group (m/sec).			

- Site work zones as identified in the Health and Safety Plan; and

- Local land use characterization (e.g., residential, commercial) within 3 kilometers of the site.

Sensitive receptor locations include schools and hospitals associated with sensitive population segments, as well as locations where sensitive environmental flora and fauna exist, including parks, monuments, and forests.

2.2.4 Environmental Characteristics

Information on environmental characteristics pertinent to a Superfund site is a necessary component for defining air pathway exposure potential. In the case of dispersion modeling, the environmental characteristics serve as key input to the modeling calculations. Environmental characteristics that should be evaluated prior to the implementation of air dispersion modeling may include:

- Climate (historical summaries from available onsite and offsite sources)
    - Annual and monthly or seasonal wind roses,
    - Annual and monthly or seasonal tabular summaries of mean wind speeds and atmospheric stability distributions,
    - Annual and monthly or seasonal tabular summaries of temperature and precipitation;

- Meteorological survey results
    - Hourly listing of all meteorological parameters for the entire monitoring period,
    - Daytime wind rose (at coastal or complex terrain sites),
    - Nightime wind rose (at coastal or complex terrain sites),
    - Summary wind rose for all hours,

  - Summary of dispersion conditions for the monitoring period (joint frequency distributions of wind direction versus wind speed category and stability class frequencies),
  - Tabular summaries of means and extremes for temperature and other meteorological parameters;

- Definition of soil conditions (for landfills and contaminated soil surfaces)
  - Narrative of soil characteristics (e.g., temperature, porosity and organic matter content),
  - Characterization of soil contamination conditions (e.g., in waste piles);

- Definition of site-specific terrain and nearby receptors

  - Topographic map of the area within 10 kilometers of the site (U.S. Geological Survey 7.5-minute quadrangle sheets are acceptable),
  - Maps that indicate the location of the nearest residence for each of the sixteen 22.5-degree sectors that correspond major compass points (e.g., north, north-northwest), nearest population centers, and sensitive receptors schools, hospitals and nursing homes);

- Maps showing the topography of the area, the location of the units of concern, and the location of meteorological monitoring equipment;

- A narrative description of the meteorological conditions during the air sampling periods, including qualitative descriptions of weather events and precipitation, which are needed for data interpretation; and

- Sensitive environmental areas (e.g., wildlife preserves, parks, etc.).

In searching for meteorological data, it is important to consider the following factors:

- Meteorological data drive the dispersion model and govern the advection and dispersion of contaminants released from a source. It is therefore important to utilize data that are considered representative of the site area and vicinity.

- The length of record for the data base should be considered to avoid a potential bias in the dispersion calculations. A minimum of 1 year of data are required to run most refined dispersion models, with 5 years being preferred. If long-term risk is the issue a meterological data period longer than 5 years may be desireable to characterize the expected exposure period.

Onsite meteorological monitoring is recommended as a part of the Superfund project planning phase. Although data collected from an onsite meteorological station may not have the long record required for their direct use in dispersion calculation, their benefits are substantial because they contain site-specific data:

- To assess the correlation with offsite meteorological data and the applicability of the offsite data to the site under consideration;

- To show the diurnal variation of the meteorological parameters affecting plume advection and dispersion; and

- To indicate any topography-induced flow, including drainage and valley flows and the effect of water bodies on wind flow, including coastal zone flow.

Therefore, it is recommended that an onsite meteorological monitoring program be initiated immediately after a site is included on the National Priorities List (NPL) if representative data are not available from the National Weather Service. (In general, National Weather Service data will be representative of site conditions for simple, flat-terrain settings.) The meteorological monitoring program should continue throughout the post-NPL phases. Elements of an onsite meteorological program (e.g., recommendations on the number and siting of meteorological stations) for a Superfund site are discussed in Section 3.4.3 of this volume, along with references for siting guidelines.

Meteorological and climatological data available from a National Weather Service (NWS) station or other suitable offsite source should be utilized (e.g. stability array [STAR] meteorological summaries). From a practical viewpoint, NWS data should be considered in most applications, since such data are subject to reasonable QA/QC programs and are processed by the National Climatic Center for use in dispersion models. Data available from state or industrial facilities should be evaluated for their applicability, the availability of parameters needed for input into the dispersion calculations, and the associated QA/QC programs. In any event, meteorological and climatological data should be obtained from a station that is considered representative of the general dispersion characteristics of the site. Factors such as proximity, topography, the existence of water bodies, and urban/rural influences should be considered in assessing the applicability of the meteorological data to the site under consideration.

Data available from the NWS are collected from either 7- or 10-meter towers. These heights are considered applicable for most Superfund low-level sources. Data from NWS stations are also applicable to the potential elevated releases, either directly or through the use of wind power law profiles.

Table 5 provides a summary of meteorological data for use in dispersion modeling for Superfund APAs.

TABLE 5. A SUMMARY OF INPUT METEOROLOGICAL DATA FOR USE IN DISPERSION MODELING FOR SUPERFUND APAs

Input Meteorological Data	Source	Length of Record
I. Superfund Step: RI/FS, Remedial Design, Operation and Maintenance.		
• Hourly average wind speed;		
• Hourly average wind direction;	• NWS	• One year minimum.
• Hourly average atmospheric stability;	• State	• Five years preferred, (a longer data set may be appropriate depending on the potential exposure period).
• Minimum and maximum daily mixing heights;	• Industrial Facilities (on-site)	
• Hourly ambient temperature.		
II. Superfund Step: Remedial Action		
A. Routine Releases		
• Hourly average wind speed;		
• Hourly average wind direction;		
• Hourly average atmospheric stability;	On-Site Meteorological Program	N/A
• Hourly ambient temperature;		
• Estimated mixing height.		
B. Non-Routine Releases		
• 15-min. average wind speed;		
• 15-min. average wind direction;		
• 15-min. average atmospheric stability;	On-Site Meteorological Program	N/A
• 15-min ambient temperature;		
• Estimated mixing height.		

Topographic features and water bodies can affect the dispersion and transport of airborne toxic constituents. It is therefore important to understand local wind flows and to identify areas with topography and/or water bodies that might influence the dispersion and transport of constituents released from the site. For example, a site located downslope of an elevated terrain feature might be affected by diurnal drainage flows. Terrain heights relative to release heights will affect ground-level concentrations. Terrain obstacles such as hills and mountains can divert regional winds. Valleys can channel wind flows and also limit horizontal dispersion. In addition, complex terrain can result in the development of local diurnal wind circulations and affect wind speed, atmospheric turbulence, and stability conditions. Although difficult to model, such situations should be recognized and quantified to the extent possible as part of the dispersion modeling analysis. Topographic maps of the facility and adjacent areas are needed to assess local and regional terrain. The utility of an on-site meteorological program also becomes apparent in these situations.

Large water bodies can also affect atmospheric stability conditions and the dispersion of air contaminants. In general, large water bodies tend to increase the stability of the atmosphere in the air layer adjacent to the water, thus reducing the dispersion of air contaminants. Local diurnal wind patterns may also be present seasonally at coastal locations. Again, onsite meteorological data can be used to identify and characterize these local wind patterns.

Soil characteristics and conditions can influence emission rates of volatile species from Superfund sites and have a large impact on the wind erosion of contaminated surface soils. It is important when considering particulate matter emissions to understand soil conditions such as porosity, silt content, particle size distribution, soil type, and source data.

Surface obstructions, including structures, trees, and vegetation, could affect air flow by generating wake effects or increasing plume dispersion due to surface roughness. It is therefore important to obtain pertinent information for use in the dispersion modeling.

2.2.5 Previous APA Data

Previous air quality data that address calculated air concentrations of contaminants known to exist at the site can provide insight into existing levels of air toxic compounds of interest. Compound-specific information will be useful in assessing what indicator compounds should be modeled and what modeling methodologies should be employed. Site-specific Superfund documents (e.g., site investigations (SIs), RI/FSs, records of decision (RODs), etc.) should be reviewed to identify available APA information.

Results of existing dispersion calculations should be evaluated for acceptability and representativeness before use. Factors to be evaluated include:

- Dispersion modeling techniques employed. These include modeling sophistication level (i.e., screening or refined).
- Input data used in the modeling, including emission inventory, meteorology, and receptor grid.
- Assumptions used to develop the input data base, the quality of data used, and their applicability to the case under consideration.
- Number of compounds modeled for and the assumptions involved.
- The assessed quality of the dispersion modeling analysis.

Existing air monitoring data for the site area can be used in designing the receptor grid and selecting compounds to be modeled. These data can also be used in evaluating the performance of dispersion modeling by comparing calculated with measured air concentrations. Most importantly, they can provide insight on existing background concentrations.

2.3 STEP 2 - SELECT MODELING SOPHISTICATION LEVEL

2.3.1 Overview

Selection of the dispersion modeling sophistication level and model is the cornerstone for a meaningful Superfund APA. Coupled with the sophistication level is the applicability of the model to the site and activity involved and the model's ability to reasonably simulate transport and dispersion of air toxic contaminants from the sources involved. The appropriate model sophistication, applicability, and capabilities will depend on the following factors:

- Source-specific APA recommendations presented in Volume I;
- Superfund dispersion modeling objectives;
- Data quality objectives for the dispersion modeling activities;
- Input data from Step 1;
- Legal and liability aspects of the Superfund project; and
- Pragmatic aspects of the program
    - Availability of good quality input data and the constraints involved,
    - Applicability of existing dispersion models to site-specific characteristics,
    - Ability of emissions models to adequately simulate emission rates and variability,
    - Ability of existing dispersion models to reasonably simulate the transport and dispersion of air toxic contaminants released from the site, considering physical and chemical factors and processes involved,

- Ability to accomplish the dispersion modeling objectives with modest uncertainties, and the availability of the required resources.

Source-specific APA recommendations have been presented in Volume I. These recommendations are based on a standard sequence of APAs. The APA strategy is based on the premise that initially a screening APA should be conducted. The need for a refined APA is then determined based on an evaluation of screening results considering the potential to exceed health criteria and modeling inaccuracies.

The dispersion modeling objectives for specific Superfund activities (e.g., RI/FS, remedial action) are also important input for the selection of modeling sophistication levels. These activity-specific objectives have been summarized in Table 1. Input from the RPM/EPM should be obtained to confirm site-specific dispersion modeling objectives and to ensure that the dispersion modeling level selected is consistent with these objectives.

The availability of appropriate meteorological data is probably the most significant factor when selecting the modeling sophistication level. Synthesized meterological data are generally limited to screening modeling while actual meterological data are appropriate for screening applications.

2.3.2 Selection of Models as a Function of Sophistication Levels

Air dispersion models are employed in a wide range of air quality studies to provide spatial and temporal fields of calculated concentrations due to air emissions from various existing and proposed sources. The calculated concentrations are used to fill data gaps generated by air monitoring programs that cannot provide measured concentrations at a large number of locations. Dispersion models provide a concentration field based on the use of a large number of receptors and consideration of a wide range of scenarios. As such, air dispersion models serve as a vital tool in assessing compliance with regulations for existing and proposed sources. They also are used extensively in the regulatory development process.

The air dispersion models utilized in air regulatory studies can conveniently be grouped into four classes: Gaussian, numerical, statistical or empirical, and physical. Of these four classes, the Gaussian models are the most widely used because of their simple formulation, ease of understanding, and their ability to simulate the transport and dispersion of air contaminants for a large number of applications. Most of the Gaussian dispersion models employed in air quality studies are point source models. They are the dominant tools in all air regulatory applications, as noted in the EPAs Guidelines on Air Quality Models. The bases of the four classes of models are:

- Gaussian models are based on the assumption that plume dispersion in the crosswind and vertical directions follows a Gaussian distribution in a uniform wind field. They are analytical solutions to the continuity equation.

- Numerical models include the continuity, momentum, and energy conservation equations that are solved numerically using various techniques. Plume transport can be in a uniform or nonuniform wind field. These models require extensive input and substantial computer and manpower resources, but may be helpful in the presence of obstructions in the wind field.

- Statistical or empirical models incorporate factors and modules that are based on experimental data. Such models can be very site-specific and may not be applicable to most of the Superfund sites and associated activities.

- Physical models are based on the use of wind tunnels or other fluid (e.g., water, oil) modeling facilities. They require major resources and are applicable for extremely difficult situations that require laboratory simulations. From a practical viewpoint, these models may not be applicable to Superfund APAs.

Of these four classes of models, Gaussian dispersion models are by far the most commonly used in air quality assessments. As discussed in Sections 2.1 and 2.2.2, the majority of Superfund sources are area sources, followed by line and volume sources. Only very few sources, mainly those present during the remedial action step, are classified as point sources. Gaussian dispersion models can and have been successfully applied to the types of sources encountered at Superfund sites; but the number of applicable models is limited.

Alternative modeling sophistication levels for Superfund APA applications can be classified as either:

- Screening models; or
- Refined models.

Screening dispersion models are applicable mainly for the screening step of the RI/FS. Their applicability and utility for any of the other Superfund activities are very limited. Screening analyses are based on conservative assumptions and/or input data. Therefore, screening modeling results provide conservative estimates of air quality impacts for a specific source. Screening dispersion models eliminate the need for further detailed modeling if they show that the impact on air quality does not pose a risk to public health and the environment. If results of screening dispersion calculations indicate a potential risk to public health and the environment, a refined modeling APA is warranted.

Table 6 provides a summary of screening dispersion modeling techniques applicable to Superfund APAs. The modeling techniques are based on EPA Guidelines and Workbooks for dispersion modeling developed for similar applications. The references for the modeling techniques are also included in Table 6. From Table 6, it is apparent that most of the screening modeling techniques apply to point sources. Such models can be used in screening analysis to approximate other source configurations, such as area sources, but

TABLE 6. A SUMMARY OF DISPERSION MODELING SCREENING TECHNIQUES FOR SUPERFUND APAs

Feature	Screening Modeling Technique				
	Screening Procedure for Estimating the Air Quality Impact of Stationary Sources, (PA, August 1988)	A Workbook of Screening Techniques for Assessing Impacts Toxic Air Pollutants USEPA, March 1988	Workbook of Atmospheric Dispersion Estimates D. Bruce Turner, 1969	Rapid Assessment of Exposure to Particulate Emissions From Surface Contamination Sites, USEPA, September 1984	ISC Dispersion Model (screening mode)
1. Source Configuration:					
Point	Yes	Yes	Yes	No	Yes^2
Line	No	No	Yes	No	Yes^2
Area	Yes	Yes	Yes	Yes	Yes^2
Volume	No	Yes	No	No	Yes^2
2. Release Mode:					
Continuous	Yes	Yes	Yes	Yes	Yes^2
Instantaneous	No	Yes^2	Yes	No	No
3. Contaminant Physical State:					
Gas	Yes	Yes	Yes	No	Yes^2
Particulate	Yes	Yes	Yes	Yes	Yes^2
4. Wake Effect	Yes	Yes	No	No	Yes^2
5. Downwash	No	No	No	No	Yes^2
6. Heavier than Air Gas Module	No	Yes^2	No	No	No
7. Number of Sources Handled	Single	Single	Single	Single	Multiple^2
8. Concentration Averaging Time	1, 3, and 24-hours, annual	Various Averaging^2 Times	Various Averaging Times	24-hour and annual	1, 3, 8, and 24-hours and annual
9. Comments	This document contains formulas and a large number of nomograms for normalized concentrations that are useful for simple screening calculations. A computerized version of this technique is in the form of the PTPLU-2 model.	This document contains formulas for screening hand calculations. Also included are examples of calculations.^{2}	This document contains formulas and a large number of nomograms for normalized concentrations that are useful for simple screening calculations. Also included are examples of calculations.	This document provides a methodology for screening estimates of air concentrations from surface releases from Superfund Sites.	The ISC dispersion model combines various dispersion algorithms into a set of two computer programs that can be used to assess the air quality impacts of emissions from a wide variety of sources.

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[1] These guidelines include a computerized model SCREEN which carries out the screening calculations.

[2] Preferred technique when applicable.

the calculations involved become tedious and subject to calculational errors. The preferred screening techniques, when applicable, for Superfund APA applications are based on the use of ISC in a screening mode and supplemented, as necessary by those stipulated in A Workbook of Screening Techniques for Assessing Impacts of Toxic Air Pollutants (U.S. EPA, 1988).

Refined dispersion models utilize analytical techniques that provide more detailed treatment of the physical and chemical atmospheric processes, more detailed and precise input data, and more specialized concentration estimates than the screening techniques. These models consist of computerized codes and can handle a massive volume of input data (e.g., several years of hourly meteorological data). Refined models generally provide more accurate estimates of the impact of Superfund sources on public health and the environment by relying on fewer assumptions and providing a consistent means of making repetitious and involved calculations without error. Frequently the conduct of a refined dispersion modeling analysis will involve a refined screening modeling as a preliminary step. The purpose of the refined screening modeling is to identify locations of high concentration using a relatively dense calculational grid network. Thus, the refined modeling analysis can be conducted in a cost-effective manner by limiting the calculational grid points to those which characterize actual receptor locations and high concentration areas of concern on a site-specific basis. Frequently, the same model can be used for both the refined screening and refined modeling analyses. Further reference to refined modeling APAs in Section 2 is based on this two-step process which includes the conduct of a refined screening analysis, as warranted.

Refined dispersion modeling provides the user with high flexibility by accommodating multiple sources and providing a concentration field for varied time averages at a large number of receptors, none of which could be obtained from hand calculations using screening methodologies. Table 7 provides a summary of refined dispersion models applicable for Superfund APAs.

TABLE 7. A SUMMARY OF DISPERSION MODELING REFINED TECHNIQUES FOR SUPERFUND APAs

	Modeling Technique			
Feature	ISC Dispersion Model[1]*	PAL DS Model[1]	Inpuff[2]	DEGADIS[3]
1. Source Configuration:				
Point	Yes*	Yes	Yes	Yes
Line	No	Yes	No	No
Area	Yes*	Yes	No	No
Volume	Yes*	No	No	No
2. Release Mode:				
Continuous	Yes*	Yes	Yes	Yes
Instantaneous	No	No	Yes	Yes
3. Contaminant Physical State:				
Gas	Yes*	Yes	Yes	Yes
Particulate	Yes*	Yes	No	No
4. Wake Effect	Yes*	No	No	No
5. Downwash	Yes*	No	Yes	No
6. Heavier than Air Gas Module	No	No	No	Yes*
7. Number of Sources Handled	Multiple	Multiple	Single	Single

(Continued)

TABLE 7. (Continued)

	Modeling Technique			
Feature	ISC Dispersion Model[1]*	PAL DS Model[1]	Inpuff[2]	DEGADIS[3]
8. Number of Meteorological Towers	Single	Single	Multiple	Multiple
9. Concentration Averaging Time	1,3,8, and 24-hour, annual	1 through 24 hours	Hourly	--
10. Applicability to Superfund Activities	All steps	All steps	Remedial Action Step	Remedial Action Step and selected use for other steps.

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[1] Include in the EPA Guideline on Air Quality Models (Revised), July 1986; ISC = Industrial Source Complex; PAL DS = Point, Area, and Line Source Dispersion Deposition.

[2] USEPA INPUFF = A single source Gaussian Puff Dispersion Algorighm - Users Guide; INPUFF = Integrated Puff.

[3] US EPA, Dispersion Model for Evaluating Dense Gas JEt Chemical Releases, Volume 1 and 2, April, 1988; DEGADIS = Dense Gas Dispersion.

* Preferred technique when applicable.

The Industrial Source Complex (ISC) dispersion model and the Point, Area, and Line Dispersion Deposition (PAL DS) model are included in the EPAs Guideline on Air Quality Models. The ISC dispersion and PAL DS models are applicable to continuous sources with several configurations, while the MESOPUFF model is applicable to instantaneous, continuous, and time-dependent releases and can handle point and area sources generally on a larger scale than most Superfund applications. Of these three, the ISC dispersion model is the preferred model for most applications and should be given first consideration as the model of choice for use in the Superfund APA for the RI/FS, remedial design, and operation and maintenance activities. It can be augmented as required under non-routine air releases by the use of the MESOPUFF II, Integrated Puff (INPUFF), or Dense Gas Dispersion (DEGADIS) models if special air release situations exist that could be simulated by any of these models.

The ISC dispersion model should also be given first consideration as the model of choice under the remedial action activities to simulate routine air releases. A model like the INPUFF or the procedure outlined in Appendix C should be utilized under nonroutine air releases.

In this respect, the ISC dispersion model can be considered the default air dispersion model for Superfund APA applications. (The ISCLT model is also included in the EPAs Graphical Exposure Modeling System, which is standard for use in conducting Superfund risk assessments.)

The PAL DS model may also be useful for estimating short-term impacts. It has a good area source treatment and it is expected to be more accurate than the ISC model for receptors immediately downwind of an area source. Furthermore, PAL DS has a more complete deposition algorithm than ISC, but it contains no downwash algorithm.

The INPUFF and the DEGADIS models were included for handling instantaneous releases, with the DEGADIS model having the capability to handle heavier-than-air gases. These two models could be useful as a part of the remedial action step on a case-by-case basis to augment EPA's A Workbook of Screening Techniques for Assessing Impacts of Toxic Air Pollutants.

2.4 STEP 3 - DEVELOP MODELING PLAN

2.4.1 Overview

A dispersion modeling plan should be developed for each Superfund APA application. The objective of the plan is to document the modeling methods, input data requirements and modeling output and use, consistent with the APA objectives and the dispersion modeling DQO. The plan also provides an opportunity for peer review and RPM/EPM approval of the modeling program. Developing a modeling plan involves the following major elements:

- Select constituents to be modeled;
- Define emission inventory methodology;
- Define meteorological data base;
- Design receptor grid;
- Detail modeling methodology;
- Estimate background concentrations;
- Define dispersion calculations to be performed; and
- Document modeling plan.

Major input to the development of the dispersion modeling plan should include the information collected under Step 1 (Collect and review input information) and Step 2 (Select modeling sophistication level.)

Procedures for development of a dispersion modeling plan are provided in the subsections that follow. Table 8 provides an outline for the modeling plan. Each of the major elements of the modeling plan is discussed in the following subsections.

TABLE 8. AN OUTLINE FOR THE DISPERSION MODELING PLAN FOR A SUPERFUND APA

I. INTRODUCTION

- General site background (site location, topography, nearby water bodies, demography, vegetation, general site activities).

II. DISPERSION MODELING DATA QUALITY OBJECTIVES

- Modeling objectives (consistent with the Superfund activity involved and the overall project objective);
- Overall rationale for the modeling approach; and
- Modeling uncertainties and their implications to the Superfund APA.

III. CONSTITUENTS TO BE MODELED

IV. EMISSION INVENTORY

- Sources to be modeled (number, configuration (i.e., point, line, area volume) locations);
- Source characteristics (constituents involved);
- Methods for estimating emissions (see Volumes II and III);
- Content of the emission inventory database (see Table 2-4);
- Particle size distribution;
- Physical and chemical properties of constituents to be modeled; and
- Dimensions of obstructions.

V. METEOROLOGICAL DATA

- Source of meteorological data;
- Length of record;
- Parameters to be utilized in the dispersion modeling; and
- Quality of the data.
- Representativeness of data.

(Continued)

TABLE 8. (Continued)

VI. RECEPTOR GRID

- On-site Receptors (number and locations);
- Perimeter Receptors (number and locations);
- Off-site Receptors
    - Regular (number and locations);
    - Extra locations in potential high concentration areas (number and locations); and
    - Environmentally sensitive locations (number and locations).

VII. MODELING METHODOLOGY

- Selected model(s) and rationale;
- Model application to the Superfund activity APA;
- Model features:
    - Rural/urban classification,
    - Wake and/or downwash effects,
    - Particle deposition,
    - Plume rise,
    - Dispersion parameters;
- Setting of model switches; and
- Testing the model against bench mark test cases.

VIII. ESTIMATED BACKGROUND CONCENTRATIONS

XI. DISPERSION CALCULATIONS

- Averaging times;
- Data summaries (tabular, graphical);
- Comparison with guideline values; and
- Input to the risk assessment.

X. REFERENCES

2.4.2 Dispersion Modeling Data Quality Objectives

The purpose of this section is to outline the main objectives of the dispersion modeling as a part of the Superfund APA and how to meet them. It should address applicable or relevant and appropriate requirements (ARARs) for each of the Superfund activities and the level of air dispersion modeling that is necessary to provide adequate input into the Superfund APA.

Elements included in this section should address:

- The overall rationale for the modeling approach;
- Model output and anticipated uncertainties, considering input data, model formulation and assumptions involved, and output; and
- Implications of model uncertainties on the Superfund APA (e.g., are they acceptable).

In this respect, dispersion modeling DQOs provide consistency in selection of the modeling tool, modeling input (emission inventory, meterological and other data) and output, and in the overall requirements of the air dispersion modeling for the specific application under consideration.

2.4.3 Select Modeling Constituents

Selection of air toxics compounds for dispersion modeling is generally less critical than for air monitoring. Selection of air monitoring compounds is significantly limited by technical, budget, and schedule constraints. However, dispersion modeling results from one target contaminant for a particular source can generally be scaled to obtain, on a cost-effective basis, concentrations for numerous other contaminants of interest.

A list of the compounds included in the Hazardous Substances List (HSL) developed by EPA for the Superfund program is presented in Table 9. This list is a composite of the Target Compound List (TCL) for organics and Target Analyte List (TAL) for inorganics. Table 9 also includes examples for additional potential Superfund air emission constituents (e.g., HCN, H2S, HCl). Therefore, Table 9 represents a comprehensive initial list of target compounds for air dispersion modeling.

Emission rates should be estimated prior to the conduct of dispersion studies. These results, as well as dispersion modeling results (as available), should be used to identify appropriate site and source-specific modeling contaminants from Table 9. In addition, contaminants included in ARARs identified during Step 1 should also be used to identify candidate modeling contaminants.

Dispersion modeling for screening applications should include all site/source-specific contaminants.

Dispersion modeling target compounds (i.e. indicator compounds) for refined APAs should, at a minimum, include all contaminants with concentrations greater than or equal to 10 percent of the appropriate health-based action level. These contaminants are expected to represent the greatest contributors to potential health impacts. This approach provides a practical basis to address refined modeling APAs at sites with a large number of potential emission compounds (e.g., over one hundred) of which only a limited subset significantly affect inhalation exposure estimates. However, it is generally recommended, as practical, to also evaluate all appropriate site/source-specific contaminants for refined modeling APAs (especially if the cumulative effect due to exposure to a mixture of constituents is used for comparison to health criteria).

The dispersion modeling target compounds list should be reevaluated, and revised if warranted, based on monitoring results.

TABLE 9. CLASSIFICATION OF ORGANIC AND INORGANIC COMPOUNDS FOR AMBIENT AIR MODELING STUDIES

Contaminant Type	Compound Class	Representative Compounds
Volatile Organics	Aromatics	benzene
		toluene
		ethylbenzene
		total xylenes
		styrene
		chlorobenzene
	Halogenated Species	carbon tetrachloride
		chlorofrom
		methylene chloride
		chloromethane
		1,2-dichloropropane
		trans-1,3-dichloropropene
		cis-1,3-dichloropropene
		bromoform
		bromomethane
		bromodichloromethane
		dibromochloromethane
		1,1,2,2-tetrachloroethane
		1,1,1-trichloroethane
		1,1,2-trichloroethane
		1,1-dichloroethane
		1,2-dichloroethane
		chlroethane
		tetrachloroethene
		trichloroethene
		1,2-dichloroethene
		1,1-dichloroethene
		1,2-dichloroethene
		vinyl chloride
	Oxygenated Species	actone
		2-butanone
		2-hexanone
		4-methyl-2-pentanone
	Sulfur-Containing Species	carbon disulfide
	Nitrogen-Containing Species	benzonitrile*

(Continued)

TABLE 9. (Continued)

Contaminant Type	Compound Class	Representative Compounds
Volatile Inorganics	Acid Gases	hydrogen cyanide* hydrochloric acid*
	Sulfur-Containing Species	hydrogen sulfide*
Semi-Volatile Organics	Phenols	phenol 2-methylphenol 4-methylphenol 2,4-dimethylphenol 2-chlorophenol 2,4-dichlorophenol 2,4,5-trichlorophenol 2,4,6-trichlorophenol pentachlorophenol 4-chloro-3-methylphenol 2-nitrophenol 4-nitrophenol 2,4-dinitrophenol 4,6-dinitro-2-methylphenol
	Esters	bis(2-ethylhexyl)phthalate di-n-octyl phthalate di-n-butyl phthalate diethyl phthalate butylbenzyl phthalate dimethyl phthalate vinyl acetate
	Chlorinated Benzenes	1,2-dichlorobenzene 1,3-dichlorobenzene 1,4-dichlorobenzene 1,2,4-trichlorobenzene hexachlorobenzene nitrobenzene 2,6-dinitrotoluene 2,4-dinitrotoluene 3,3′-dichlorobenzidine
	Amines	n-nitrosodimethylamine n-nitrosodi-n-propylamine n-nitrosodiphenylamine aniline 2-nitroaniline 3-nitroaniline 4-nitroaniline 4-chloroaniline

(Continued)

TABLE 9. (Continued)

Contaminant Type	Compound Class	Representative Compounds
Semi-Volatile Organics (cont.)	Ethers	bis(2-chloroethyl)ether bis(2-chloroisopropyl)ether bromophenyl-phenylether 4-chlorophenyl-phenylether
	Alkadienes	hexachlorobutadiene hexachlorocyclopentadiene
	Miscellaneous Aliphatics and Aromatics	benzoic acid benzyl alcohol bis(2-chloroethoxy)methane dibenzofuran hexachloroethane isophorone
	Polynuclear Aromatic Hydrocarbons (PAHs)	acenaphthene acenaphthylene benzo(a)anthracene benzo(b)fluoranthene benzo(k)fluoranthene benzo(g,h,i)perylene benzo(a)pyrene chrysene dibenz(a,h)anthracene fluoranthene fluorene indeno(1,2,3-cd)pyrene naphthalene 2-methylnaphthalene 2-chloronaphthalene phenanthrene pyrene
	Pesticides	alpha-BHC beta-BHC delta-BHC gamma-BHC heptachlor heptachlor epoxide 4,4′-DDT 4,4′-DDD 4,4′-DDE

(Continued)

TABLE 9. (Continued)

Contaminant Type	Compound Class	Representative Compounds
Semi-Volatile Organics (cont.)	Pesticides (cont.)	endrin endrin ketone endrin aldehyde endosulfan I endosulfan II endosulfan sulfate aldrin dieldrin chlordane methoxychlor toxaphene
	Polychlorinated Biphenyls (PCBs)	Arochlor 1016 Arochlor 1221 Arochlor 1232 Arochlor 1242 Arochlor 1248 Arochlor 1254 Arochlor 1260
Semi-Volatile Metals	----	Mercury
Non-Volatiles	Inorganic Metals and Non-metals	aluminum antimony arsenic barium beryllium cadmium calcium chromium cobalt copper iron lead magnesium manganese nickel potassium selenium silver sodium thallium tine vanadium zinc

NOTE: Compounds identified by an asterisk (*) are not contained on the US EPA Hazardous Substance List (HSL).

It is recommended that dispersion modeling results initially be obtained in terms of dispersion factors (i.e., concentration divided by a unit emission rate). This will provide a cost-effective basis for estimating receptor exposure concentrations for a wide variety of emission constituents (i.e., a compound-specific concentration equals the dispersion factor of the receptor location of interest times the compound-specific emission rate).

2.4.4 Define Emission Inventory Methodology

An emission inventory is a key input to the Superfund air dispersion modeling. Data obtained from Step 1 (Collect and review input information) should be utilized in determining the number and nature of sources involved. The modeling plan should outline the procedures for:

- Estimating the dimension of the sources involved. This includes estimating the contaminant distribution and defining the shape and boundaries of sources.

- Classifying sources by configuration--area, line, volume, and point--and subdividing them as necessary.

- Determining coordinates of the sources.

- Defining the constituents involved with each source based on the output of Section 2.4.3.

- Defining the parameters required for estimating emissions that are identified in Volumes II and III, and the rationale for their selection.

- Calculating emissions based on methods outlined in Volumes II and III.

- Estimating particle size distribution for calculating particulate deposition.

- Accounting for downwash from nearby structures. This phenomenon is particularly important for onsite air strippers and incinerators at Superfund sites. These units frequently have low stack heights. Therefore, releases from these stacks may be influenced by adjacent structures.

- Estimating the dimensions of obstructions and the distance of such obstructions from the sources under consideration.

Program design objectives and DQOs should be an integral part of the methodology outlined.

The emissions inventory should be tabulated in a format suitable for use in dispersion modeling. This table should include physical and chemical characteristics of the constituents to be modeled.

As previously discussed, most of the Superfund air release sources are area sources, followed by line and volume sources and to a lesser extent by point sources. Many of the area sources at Superfund sites have irregular shapes and many cover a large area (e.g., many acres). The ISC dispersion model handles area sources only as squares. To accommodate the ISC model input requirements, it may be necessary to subdivide a Superfund area source into a number of smaller area sources, square in shape. Source subdividing into small, square area sources has the following two major benefits:

- The areas and shapes of irregular sources can be approximated in most cases by a number of small squares, as illustrated in Figure 3.

- Receptors at or near the source can also be included in the dispersion modeling, as often required for the Superfund APA. This includes receptors at onsite work areas, at the site perimeter, and immediately offsite.

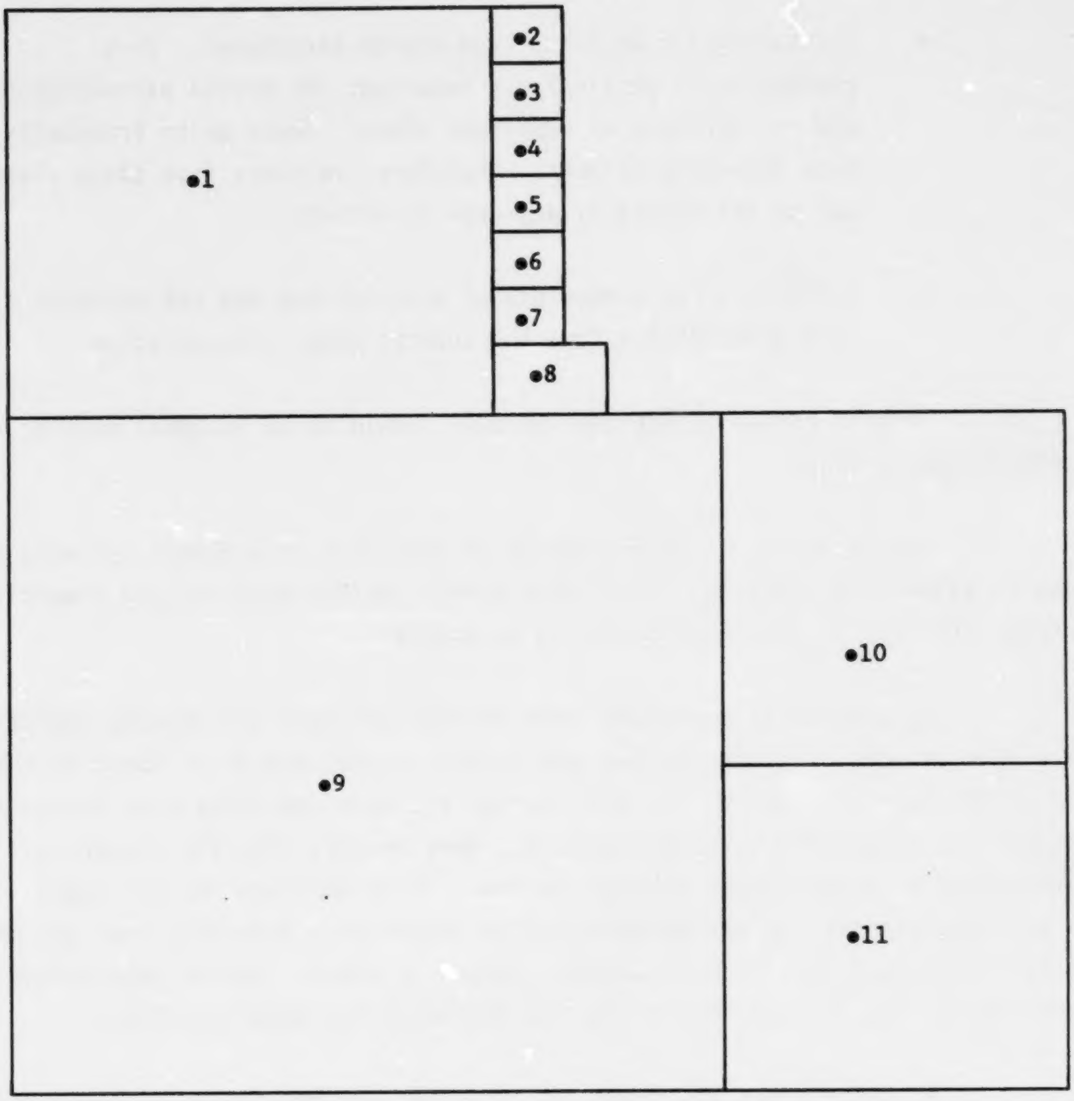
1
2
3
4
5
6
7
8
9
10
11

Figure 3. Representation of an Irregularly Shaped Area Source.

A specialized modeling approach is generally needed for standard Gaussian dispersion models such as the ISC, in order to obtain concentration estimates near the boundary of a large area source. For example, the nested-area subdivision approach illustrated in Figure 4 can be used. By subdividing the area source such that the square nearest the receptor is less than 10 meters on a side, it is possible for the ISC dispersion model to provide estimates of concentration within 1 meter of the source boundary.

Flux models, which simulate the microscale physics immediately above a ground-level emission surface, can also be used to estimate concentration at and in the vicinity of an area source. Although these flux models can be technically sophisticated, they generally lack extensive validation and are not recommended as preferred models for Superfund APAs.

2.4.5 Define Meteorological Data Base

Meteorological data are also key input to the dispersion calculations. As noted, input meteorology governs the transport and dispersion of the contaminant plume. It is therefore imperative to select the most appropriate meteorological data. For most Superfund activities (RI/FS, remedial design, and operation and maintenance), historical data are very useful. In the absence of a long record of onsite data, data applicable for use in dispersion modeling are generally available from NWS stations, state meteorological programs, and private industry. Generally at least one year of meteorological data should be available for screening analyses. It is desirable to have five or more years of meteorological data to support long-term exposure assessments for refined APAs.

As discussed in Section 2.2.4, onsite meteorological data should be used:

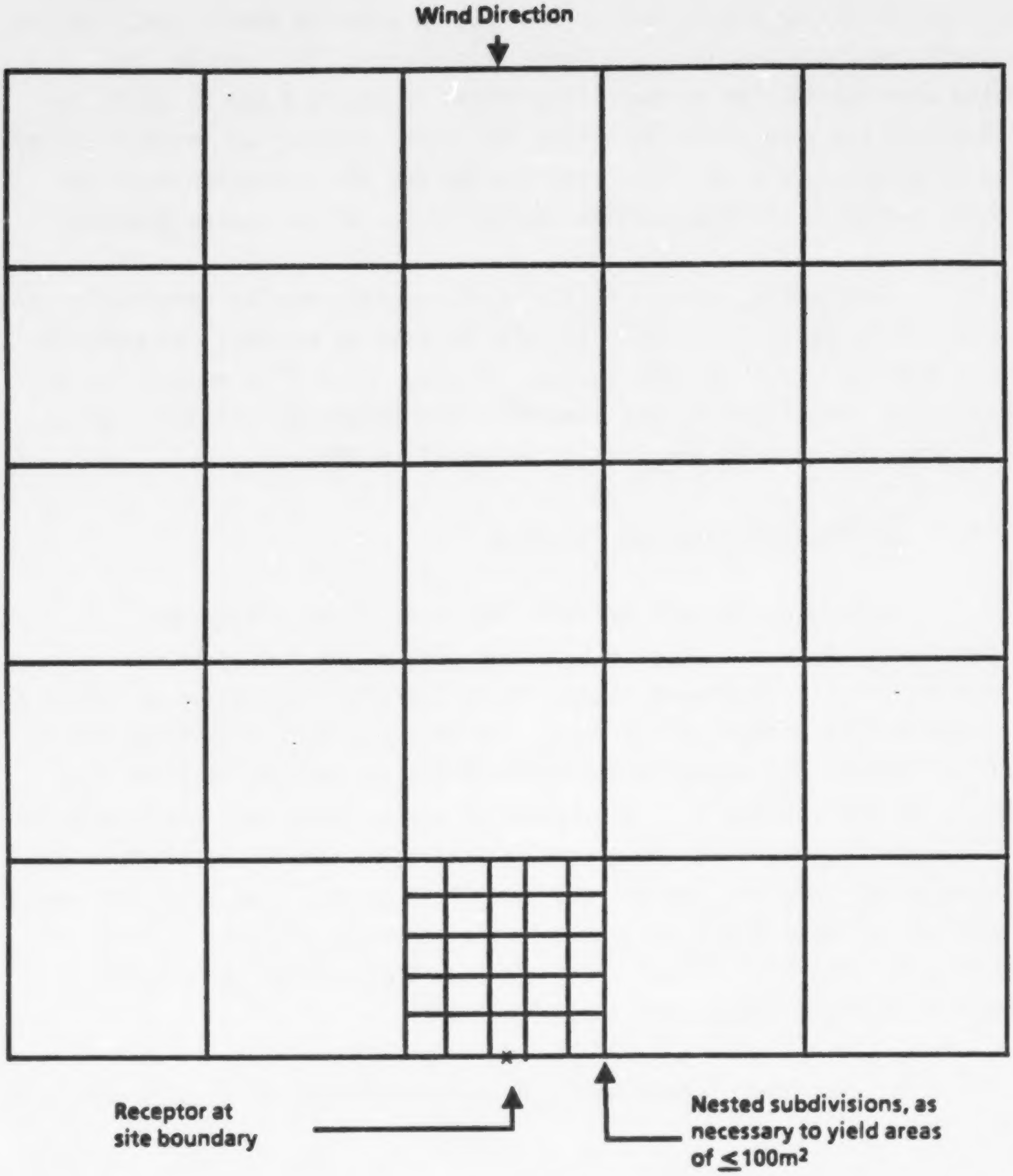
Wind Direction
Receptor at site boundary
Nested subdivisions, as necessary to yield areas of ≤100m²

Figure 4. Example of Nested Subdivision of Area Source.

- To evaluate (correlate) offsite data;
- To provide site specific data showing the diurnal variations of the meteorological parameters and the effects of topography and nearby water bodies on the transport and dispersion of the air toxics plume; and
- Define worst-case emission/dispersion scenarios to conservatively evaluate short-term exposure conditions to support screening APAs. Worst-case scenarios should represent the highest impact resulting from the combination of meteorological conditions giving high emissions and low dilution.

The data base selected should meet program and DQO objectives, have a record of sufficient length, and include data representative of the site area. Some guidance on the determination of representativeness of meteorological data can be found in the "On-Site Meteorological Program Guidance" document referenced below. Due to uncertainties associated with the use of off-site data, it is often advisable to establish an on-site measurement program as early in the site remediation process as possible.

Meteorological data may be used to define worst-case emission/dispersion scenarios to conservatively estimate short-term exposure conditions to support screening APAs. For example, this approach would be appropriate for use of ISCST for a screening APA. However, for a refined APA based on ISCST a sequential file of hourly meteorological data may be warranted as modeling input.

The quality of the meteorological data should meet EPA requirements as outlined in the following technical references:

- U.S. EPA. June 1987. On-Site Meteorological Program Guidance for Regulatory Modeling Applications. EPA-450/4-87-013. Office of Air Quality Planning and Standards. Research Triangle Park, NC 27711.

- U.S. EPA. February 1983. Quality Assurance Handbook for Air Pollution Measurements Systems: Volume IV. Meteorological Measurements. EPA-600/4-82-060. Office of Research and Development. Research Triangle Park, NC 27711.

- U.S. EPA. July 1986. Guidelines on Air Quality Models (Revised). EPA-405/2-78-027R. NTIS PB 86-245248. Office of Air Quality Planning and Standards. Research Triangle Park, NC 27711.

- U.S. EPA. November 1980. Ambient Monitoring Guidelines for Prevention of Significant Deterioration (PSD). EPA-450/4-80/012. NTIS PB 81-153231. Office of Air Quality Planning and Standards. Research Triangle Park, NC 27711.

The modeling plan should also identify the following information with respect to the meteorological data set:

- Source of meteorological data and rationale for selecting this data base. This applies to both surface and upper-air data.

- Length of record. A minimum of 1 year of hourly data is required, with 5 years of data being preferred.

- Parameters to be utilized in the dispersion model, including wind speed, wind direction, atmospheric stability, ambient temperature, and mixing height.

An onsite meteorological program is recommended in the case of the remedial action step. Section 3.0 addresses the requirements of onsite meteorological programs for that step. Even flat terrain sites with nearby National Weather Service data should install and operate an onsite meteorological station during remedial actions. The short-term temporal and spatial variability of wind conditions limits the applicability of offsite meteorological data for realtime decision-making (e.g., during non-routine air releases). Data collected through this step can be utilized as historical data in making the dispersion calculations and in assessing routine air releases, or as near real time data in estimating the impact of nonroutine air releases. The modeling plan for the remedial action step should address the use of onsite meteorology in dispersion modeling for both routine and nonroutine releases.

Meteorological parameters used for each application should be identified, and an explanation should be given of their use.

2.4.6 Design Receptor Grid

The selection of the proper number and locations of receptors is paramount for a meaningful dispersion modeling analysis. It is therefore important to carefully select receptors to ensure that the areas of potential impact include the desired spatial distribution of receptors.

A receptor grid or network for a Superfund air dispersion model defines the locations of calculated air concentrations that are used as a part of the APA to assess the effect of air releases on human health and the environment under the various Superfund site activities.

The process of setting the receptor grid should meet the following APA objectives:

- Provide concentration estimates which can be used as input to the Superfund risk assessment process and to compare to ARARs; and

- Provide technically sound spatial distribution of receptors to account for areas exhibiting large concentration gradients over short distances, by increasing the density of receptors at these locations and ensuring that locations of high concentrations are not missed.

It is therefore important to establish a receptor grid that will address both the locations of anticipated maximum air toxics concentration and the air toxic concentrations at environmentally sensitive receptors such as residences, work areas, schools, hospitals, parks, and monuments.

Concentration averaging times should be a factor in setting the receptor grid based on the APA objectives. For short-term averaging times (up to 24 hours), the selection of receptors should be based on the objective of protecting public health and the environment at all publicly accessible areas around the Superfund site. In this respect the receptor should include locations of anticipated maximum air toxics concentration offsite. With respect to long averaging times (monthly, seasonal, annual, 70 years, or others) air toxics concentrations should be evaluated at actual receptor locations (i.e., in areas surrounding residences, work places, and at locations with environmentally sensitive species).

From a practical viewpoint, most of the Superfund release sources can be regarded as ground-level sources. Only a few of them are elevated, and even they are classified as low-level elevated sources. Examples include onsite structures and onsite treatment facilities (e.g., incinerators, air strippers). This implies that, for most releases from Superfund sources, high-ground-level concentrations of air toxics will occur at short distances from the source. Depending on the source configuration and the release height, such concentrations will occur less than 1 to 2 kilometers from the source.

The receptor grid system for Superfund APAs should be developed on a case-by-case basis. The basic objective is to resolve concentration gradients in the vicinity of the site and to identify maximum concentrations. Receptor grid design should also consider the following:

- Results of the receptor data evaluation performed under Section 2.2.3;
- Results of screening and refined screening dispersion modeling that can be invaluable in terms of identifying gradients and potential locations of high concentrations;
- Prevailing wind direction;
- Meteorological conditions conducive to high concentrations;
- Population distribution in the site vicinity (Section 2.2.3);
- Sensitive receptor locations;
- The number and configuration of sources;
- Release characteristics such as height, dimensions, and proximity to the site perimeter;
- Work areas on the site; and
- Locations of air monitoring stations.

Screening analyses, especially for short-term exposure evaluations may be based on worst-case meteorological scenarios which assume invariant wind conditions. Therefore, for a single source evaluation based on these conservative assumptions, the screening analysis calculational grid points may be limited to the plume centerline for the downwind sector of interest.

These factors should be considered in selecting onsite, perimeter, and offsite receptors. The rationale for the selection of the number and locations of each type of receptor should be stated. Depending on the specific application, the number of receptors in a refined analysis could range from 200 to 400.

2.4.7 Detailed Modeling Methodology

The modeling methodology is based on the objectives outlined in Table 1 for dispersion modeling as a function of the Superfund activity, and it is consistent with the DQOs for the project. As discussed in Section 2.4.2, it is necessary to determine the level of sophistication of the dispersion modeling, the input data requirements, and the quality of data. This determination will permit assessment of the costs and benefits of the modeling methodology and the effects of the uncertainties involved on the Superfund APA.

Screening modeling is useful for obtaining rough upper-bound estimates of the levels of air contaminant concentrations and the approximate locations of high concentrations and providing information on the need for refined dispersion modeling. Screening models are presented in Table 6. The selected methodology should take into account the following:

- Screening versus refined modeling applications;
- Formulation to be used;
- Applicability of the approach to the Superfund activity and source under consideration;
- Concentration averaging time;
- Special considerations such as downwash;

- Dispersion parameters;

- Plume rise considerations; and

- Quality and quantity of meteorological data available (e.g., the availability of representative data recommended to support refined dispersion modeling analyses).

For refined dispersion modeling, the model to be used should be selected from Table 7. The ISC dispersion model is the preferred model for most Superfund APAs. When there is a need for characterizing time-dependent releases, the INPUFF model should be utilized. Other models listed in Table 7 could also be used on a case-by-case basis.

The dispersion modeling plan should address the following for refined modeling:

- Selected model and rationale;

- Model applicability, as determined by the Superfund activity involved and source characteristics. For example, nonroutine releases during the remedial action step should be considered when the model is selected;

- The rural or urban character of the area, based on demographic data;

- Wake and/or downwash effects, including those attributable to onsite obstructions;

- Particle deposition, taking into consideration the particle mass-size distribution;

- Plume rise and dispersion parameters, including initial dilution parameters; and

- Model switches (tabulation).

In addition, a brief synopsis of the model formulation should be discussed.

2.4.8 Estimated Background Concentrations

Background air concentrations are an integral part of many air quality studies that involve dispersion modeling. Such information is useful in estimating the cumulative impact of air toxic contaminants as well as the incremental impact of the Superfund site activities. The major application for background concentration estimates is to assess conformity with ambient air quality criteria for ARARs.

Measurement of air quality in the vicinity of a Superfund site could provide the necessary information on existing background air quality levels, providing the following are met:

- The air monitoring network was designed and implemented following procedures similar to the guidelines provided in Section 3.0.

- The network monitored several of the site-specific target compounds.

Background air quality data could be obtained from previous air monitoring programs conducted in the site vicinity, as discussed in Section 2.2.5. It also could be obtained through the implementation of an air monitoring program in the vicinity of the site as a part of the Superfund site activity. In areas where there are large sources of toxic air pollutants close to the Superfund site, modeling these sources can be performed in order to determine background concentrations.

The modeling plan should address the subject of background air quality for the Superfund project and delineate the process for estimating background levels based on existing data, proposed air monitoring, or additional modeling. The project objectives and DQOs should serve as a key factor in assessing the background levels in the vicinity of the site.

2.4.9 Define Dispersion Calculations To Be Performed

Once the overall scheme for dispersion modeling has been outlined, the dispersion calculations to be performed must be defined. This includes the following:

- Averaging times for calculating concentrations,
    - Short term: hourly and 3-, 8-, and 24-hours.
    - Long term: monthly, seasonal, annual, or other;
- Dispersion modeling scenarios as a function of the Superfund activity under consideration. For example, the RI/FS activity may require modeling the no-action scenario or scenarios associated with the alternative remedial actions. The remedial design activity may require modeling a few scenarios associated with a specific onsite technology; and
- The reporting format for calculated results,
    - Tables summarizing receptors that exhibit high concentrations and sensitive receptors with associated concentrations, for various averaging times.
    - Isopleths of concentrations for the site area.

The modeling plan should outline the type of dispersion calculations to be performed and present results of the calculations.

2.4.10 Document the Modeling Plan

The modeling plan should be documented according to the discussion provided in Sections 2.4.2 through 2.4.8, utilizing the outline suggested in Table 9.

2.5 STEP 4 - CONDUCT MODELING

2.5.1 Overview

Dispersion modeling for Superfund APA applications should be conducted consistent with the modeling plan developed during Step 3. However, successful implementation of the modeling plan requires qualified modelers and attention to QA/QC factors such as verifying all model input files.

2.5.2 Staff Qualifications and Training

Dispersion modeling is a complex process that requires specialized qualifications and training. This aspect of modeling has been frequently overlooked as personal computer (PC) versions, which are easy to use, have become prevalent. However, it is also easy for the novice to select inappropriate modeling options and/or enter data incorrectly. These errors can be subtle in nature and difficult to detect, and they can significantly affect the validity of the modeling output. Also, interpretation of modeling data requires a thorough understanding of the theory on which the model is based and on input data/model limitations. Therefore, it is imperative that a qualified dispersion modeler thoroughly familiar with the modeling process and the required QC documentation be assigned to provide dispersion modeling support for Superfund APA applications.

2.5.3 Performance of Modeling

This section addresses the process of performing dispersion modeling for a Superfund APA with emphasis on quality control. The modeling can be executed by hand calculation or computer models when screening dispersion modeling (depending on which of the alternative approaches listed in Table 6 is selected) is considered. It is implemented with a computer when refined dispersion modeling is performed.

The screening dispersion modeling process includes the following steps:

- Calculate the emission release rate or total release;
- Derive the source parameters required as additional input;
- Define the special parameters required to estimate wake effects or negative plume buoyancy;
- Select the meteorological data set or scenario to be modeled;
- Define the receptors for which calculations will be performed;
- Perform the calculations (generally using computer models); and
- Obtain conservative concentration estimates.

The benefits of simplicity in screening techniques can be easily lost if repeated calculations introduce a higher probability of computational errors. Screening calculations should always be accompanied by adequate documentation to permit QC checks on the simulations.

The refined dispersion modeling process includes the following basic tasks:

- Develop the emission inventory;
- Preprocess the meteorological data;
- Develop the receptor grid (this generally involves refined screening modeling as previously discussed);
- Run bench mark test cases;
- Verify the input files;
- Perform model calculations; and
- Obtain more realistic concentration estimates;

The modeling process is delineated in Figure 5. The tasks involved in these steps must be executed carefully to minimize the likelihood of errors. A small error in one of the input data files will require rerunning the model, thus increasing the expenses of the project. Subsequent sections address the refined dispersion modeling process. A similar but simpler discussion applies to the screening modeling.

Develop Emission Inventory

This task calls for utilizing input data collected under Step 1 (Collect and review input information) (see Section 2.2) and developing an emission inventory and other source data required as input to the dispersion model. The overall process of developing this data base was outlined in Sections 2.4.3 and 2.4.4. The emission inventory is developed using source-specific formulas, factors, and procedures described in Volumes II and III of this Guideline. Calculated emissions and related parameters should be verified and tabulated in a format similar to that presented in Table 3.

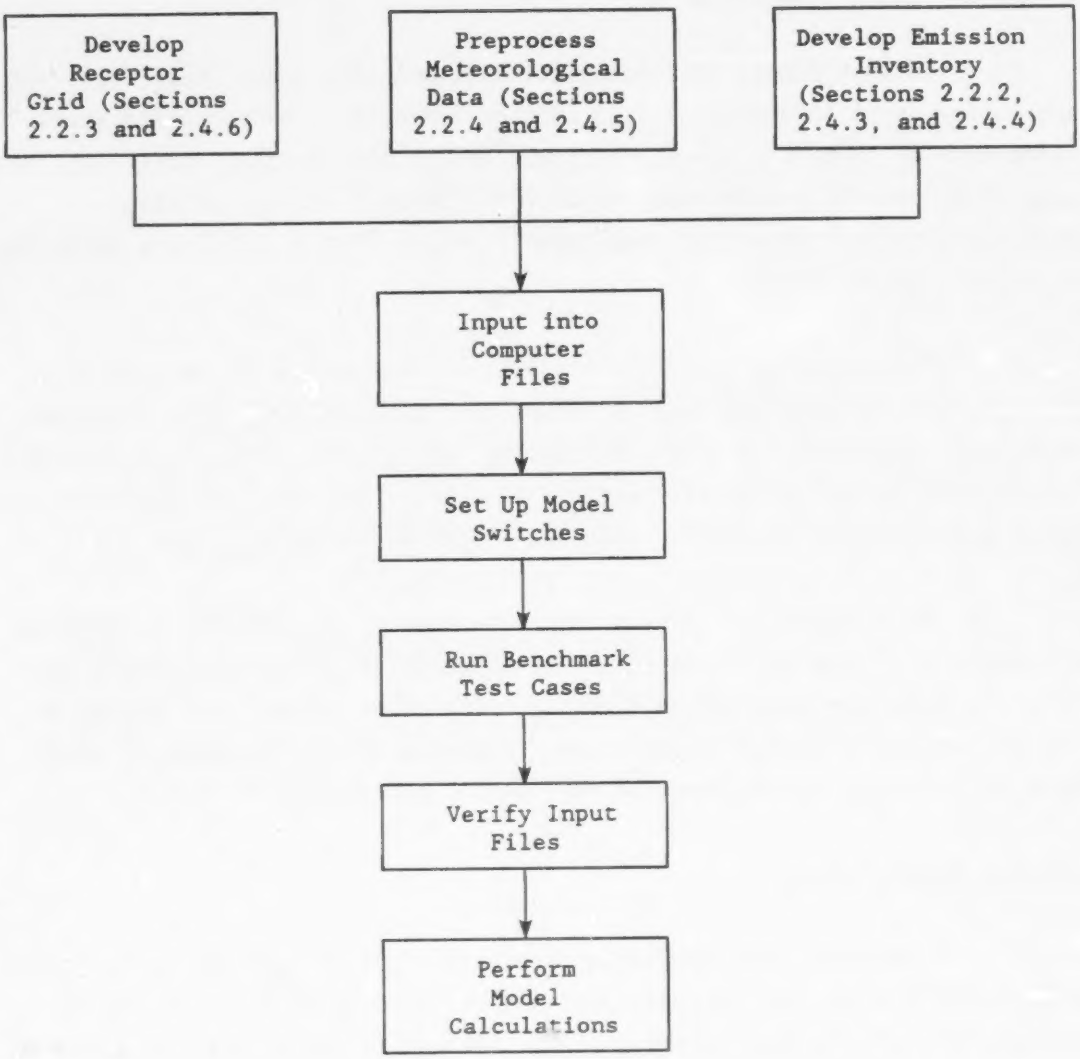
Develop Receptor Grid (Sections 2.2.3 and 2.4.6)
Preprocess Meteorological Data (Sections 2.2.4 and 2.4.5)
Develop Emission Inventory (Sections 2.2.2, 2.4.3, and 2.4.4)
Input into Computer Files
Set Up Model Switches
Run Benchmark Test Cases
Verify Input Files
Perform Model Calculations

Figure 5. The Dispersion Modeling Process.

Preprocess Meteorological Data

In most cases, meteorological data compiled under Step 1 (Collect and review input information) (see Section 2.2.4) must be processed (e.g., using MPRM or RAMMET) prior to their use in the dispersion calculations, to make them compatible with model input requirements. Model-specific meteorological preprocessing requirements are defined in the users guide for each EPA dispersion model.

Preprocessing generally involves a large volume of data (e.g., 1 year of data includes 8760 hourly values for each meteorological parameter under consideration). In refined modeling, the preprocessing is done with a computerized preprocessor that accepts on-site or NWS data and generates a processed data base compatible with the dispersion modeling code.

The meteorological data should be handled as outlined in Sections 2.2.4 and 2.4.5 and as discussed in reference material associated with each modeling technique (see Tables 7 and 8). The preprocessed data should be checked for validity before their use. Recommendations for meteorological data validity checks are provided in Table 10 and in Section 3.6.2.

Develop Receptor Grid

A receptor grid should be developed based on data collected under Step 1 (Collect and review input information) (see Section 2.2.3) and the process outlined in Section 2.4.6. The grid can be rectangular or circular, or it can consist of a selected number of receptors located at special locations. In general, all three forms are utilized by most of the refined models included in Table 7. The spatial distribution of receptors should be determined based on factors discussed in Section 2.2.3 and on site-specific considerations. Once the grid has been established and coordinates assigned using U.S. Geologic Survey (USGS) maps, the data base can be put into a receptor file in a format compatible for use by a refined dispersion model.

TABLE 10. SUGGESTED METEOROLOGICAL DATA SCREENING CRITERIA[a]
(U.S. EPA, JUNE 1987)

Meteorological Variable	Screening Criteria[a]
Wind Speed	Flag data if the value: o Is less than zero or greater than 25 m/s; o Does not vary by more than 0.1 m/s for 3 consecutive hours; and o Does not vary by more than 0.5 m/s for 12 consecutive hours.
Wind Direction	o Is less than zero or greater than 360 degrees; o Does not vary by more than one degree for more than three consecutive hours; and o Does not vary by more than ten degrees for 18 consecutive hours.
Temperature	o Is greater than the local record high; o Is less than the local record low; (The above limits could be applied on a monthly basis.) o Is greater than a 5° change from the previous hour; and o Does not vary by more than 0.5°C for 12 consecutive hours.
Temperature Difference	o Is greater than 0.1°C/m during the daytime; o Is less than -0.1°C/m during the nighttime; and o Is greater than 5.0°C/m or less than -3.0°C/m.

[a] Some criteria may have to be changed for a given location.

The number of receptors may be limited for screening modeling based on conservative input assumptions (e.g., worst-case, short-term meteorological scenarios based on invariant wind conditions). However, as previously discussed, a more comprehensive receptor grid network is generally warranted for refined screening modeling analyses to identify high concentration areas. The results from the refined screening analyses may be used to limit the calculational grid network to significant receptor locations for refined modeling APAs.

The coordinate of each receptor point should be verified as a routine QC measure.

Run Benchmark Test Cases

Two additional activities have to be performed prior to the execution of actual dispersion model runs in the case of refined modeling.

The first involves model runs with benchmark test cases to ensure that the model performs as specified. It is recommended that benchmark cases accompanying the dispersion model be utilized and results be checked against these cases.

The second activity involves the setting of model switches in accordance with the case under consideration. Switches provide the user with the program setting options pertaining to input, dispersion model, and output. Examples include receptor grid (rectangular or polar), rural or urban mode, building wake and stack tip downwash effects, printout of the 50 maximum concentration values, and annual average concentrations. It is important in this case to consider the type of model output, based on the options available, to avoid excessive printout without any use for most of it. From a practical viewpoint, daily and annual concentrations are the most useful in assessing air release effects through the APA. Once it has been determined that the model performs properly and the appropriate switches have been set, the model is ready for execution.

Perform Model Calculations

Once the input data files have been prepared and verified, the model tested, and the switches set properly, the actual dispersion model calculations are performed in accordance with the modeling plan.

2.6 STEP 5 - SUMMARIZE AND EVALUATE RESULTS

2.6.1. Overview

Modeling results available from Step 4 should be summarized and evaluated to provide input to site-specific APA and the Superfund decision-making process. The recommended approach for this step is as follows:

- Summarize data;
- Evaluate modeling results; and
- Prepare a report.

Output of the dispersion modeling should be summarized together with pertinent source and meteorological data to serve as a basis for data evaluation. Calculated concentrations and their location can be used to compare with ARARs or as part of the exposure assessment input to a risk assessment. The performance of the dispersion modeling for existing sources could be assessed by comparing calculated and measured air concentrations.

Results of the dispersion modeling, together with information on the methodology employed, should be summarized in a modeling report.

2.6.2 Summarize Data

In general, the output of computer model calculations is given in a tabular form. These data have to be summarized in a form that is useful for the specific APA application. Examples of recommended tabular data summaries for air toxics indicator constituents include:

- Daily concentrations at sensitive receptor locations included in the dispersion calculations;
- Maximum long-term (monthly, seasonal, annual, or other) calculated concentrations;
- Daytime and nighttime maximum and average concentration estimates (for complex terrain and coastal sites only);
- Calculated long-term concentrations at sensitive receptors;
- ARARs;
- Summaries of calculated versus measured (as available) concentrations for short- and long-term averaging times; and
- Source-specific summaries for Superfund sites with multiple air release sources.

A useful presentation of the results in graphic form is accomplished by plotting concentration isopleths for indicator constituents. These isopleth summaries depict the areas affected by Superfund air release sources. Plots can be generated using specialized software (e.g. SURFER) or using an integrated modeling/plotting software package. Figure 6 is an example of a computer-generated, ground-level isopleth plot.

Frequently, it may not be practical to place air monitoring stations at offsite receptor locations of interest. However, it may be necessary to characterize concentrations at these locations as input to site-specific risk assessments. In these cases, concentration patterns based on modeling results can be used to extrapolate concentrations monitored onsite to offsite locations. An illustration of modeling results for this application is provided in Figure 7.

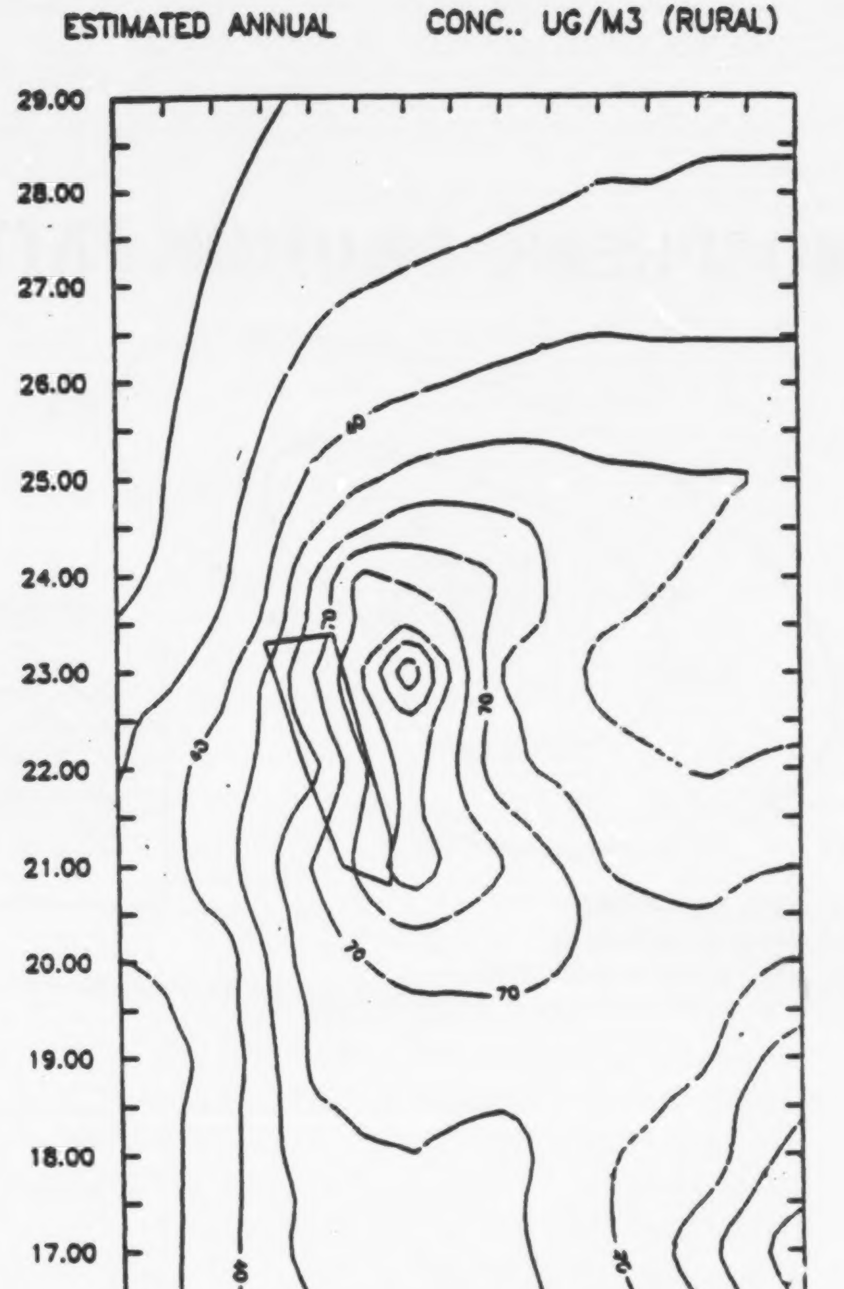

Figure 6. Example of a Computer Generated Ground Level Isopleth Plot.

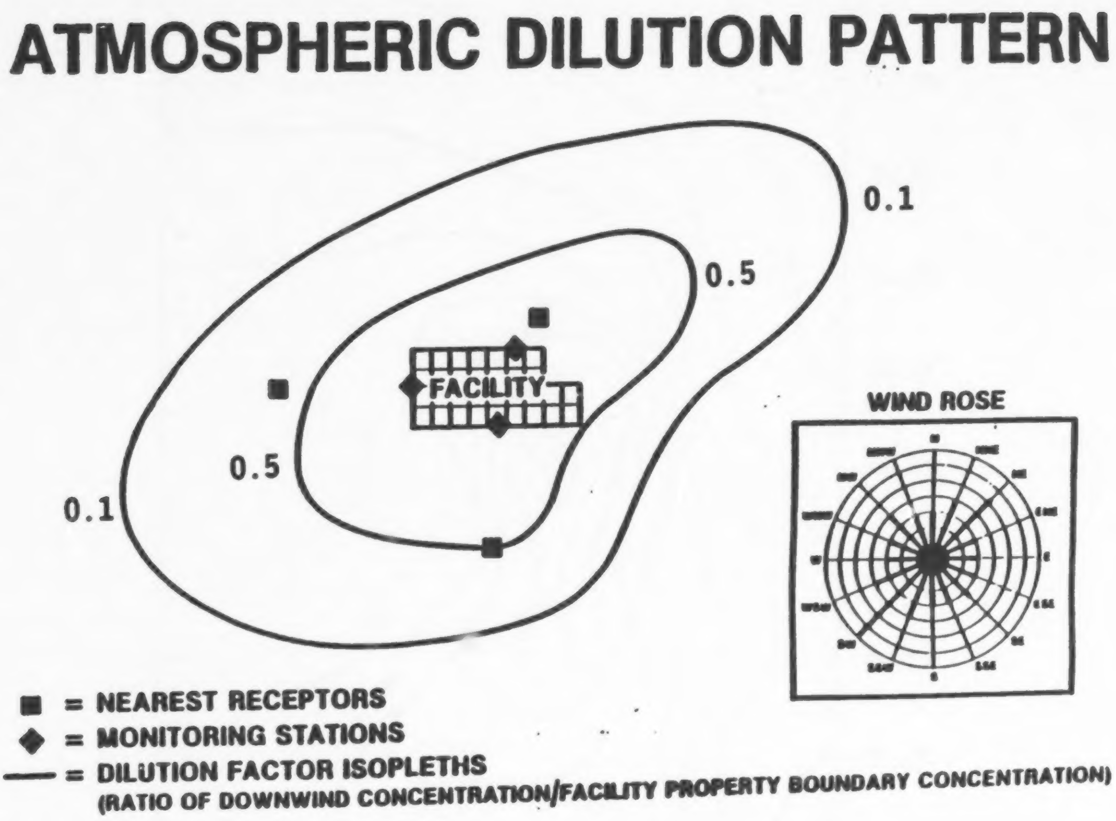
ATMOSPHERIC DILUTION PATTERN
0.1
0.5
FACILITY
0.5
0.1
WIND ROSE
■ = NEAREST RECEPTORS
◆ = MONITORING STATIONS
—— = DILUTION FACTOR ISOPLETHS
(RATIO OF DOWNWIND CONCENTRATION/FACILITY PROPERTY BOUNDARY CONCENTRATION)

Figure 7. Example Atmospheric Dispersion (Dilution) Pattern.

Meteorological data summaries should include the following at a minimum:

- Daytime wind rose (only for coastal or complex terrain areas);
- Nighttime wind rose (only for coastal or complex terrain areas);
- Summary wind rose;
- Summary of dispersion conditions for the sampling period (joint frequency distributions of wind direction versus wind speed category and stability class frequencies, or Stability Array (STAR) summaries;
- Tabular summaries of means and extremes for temperature and other pertinent meteorological parameters; and
- Data recovery summaries for all parameters.

Statistical summaries for the meteorological data should be presented on a monthly, seasonal, and annual basis as well as for the entire modeling period. For sites with diurnal wind patterns (e.g., complex terrain or coastal areas), the modeling should include separate wind roses for daytime and nighttime conditions and a summary wind rose (for all wind observations during the monitoring period).

Data recovery information should also be presented to evaluate data representativeness. A minimum data recovery target should be 90 percent.

2.6.3 Evaluate Modeling Results

Modeling results should be carefully evaluated and interpreted to provide input to the Superfund risk assessment process. Factors that should be considered during this data evaluation phase include:

- Modeling concentrations;
- Source receptor relationship; and
- The need for supplemental analyses.

Modeling results should also be compared to ARARs considering the above data interpretation factors. In addition, interpretation of dispersion modeling results should account for additional factors such as complex terrain, variable winds, multiple contaminant sources, and intermittent or irregular releases.

In situations where multiple sources are being modeled, it is important to consider source-specific contributions to predicted concentrations. For example, remediation sources may involve soil handling activities and an air stripper. Maximum impacts may be dominated by soil handling operations, and this information is important to determining what emission controls are effective in reducing maximum concentrations to acceptable levels.

Model Uncertainty/Receptor Applicability

Field validation studies of Gaussian models have consistently demonstrated that estimates of model uncertainty are largely inadequate, particularly in their quantification of the representativeness of data and the non-homogeneous and stochastic nature of atmospheric dispersion which are not handled in models. These studies have shown that the predicted locations of maximum concentrations based on modeling results may not correspond with the location of the maximum value based on field measurements. Therefore, the recommended approach is to consider maximum concentrations predicted off site as controlling concentrations irrespective of whether the maximum receptor coincides with a residence. This is particularly important for short-term (i.e., 24-hours or less) concentrations. For long-term concentrations, the location of maximum receptors in relation to residences can be considered on a case-by-case basis as a factor in evaluating model results.

Supplemental Analyses

Supplemental analyses may be warranted at complex terrain or coastal locations in order to apply dispersion modeling results to Superfund APA applications. These supplemental analyses may involve additional modeling (e.g., wind flow field models, physical models, specialized mesoscale models) to characterize local transport and/or diffusion conditions. Frequently it may be necessary to conduct specialized field studies that may involve intensive meteorological monitoring materials and/or tracer studies.

Figures 8 and 9 illustrate an example application of supplemental analyses. This Superfund site is located on the sloping terrain of a valley wall. Available dispersion models could not adequately characterize the very localized dispersion conditions. However, receptors were located at the site perimeter, and it was necessary to characterize potential impacts associated with soil handling operations at the onsite landfill. Smoke and SF_6 tracer studies were used to define transport paths for typical drainage flow conditions. These results are summarized in Figure 8. Results from the tracer studies were also used to develop a site-specific dispersion model. These results are summarized in Figure 9.

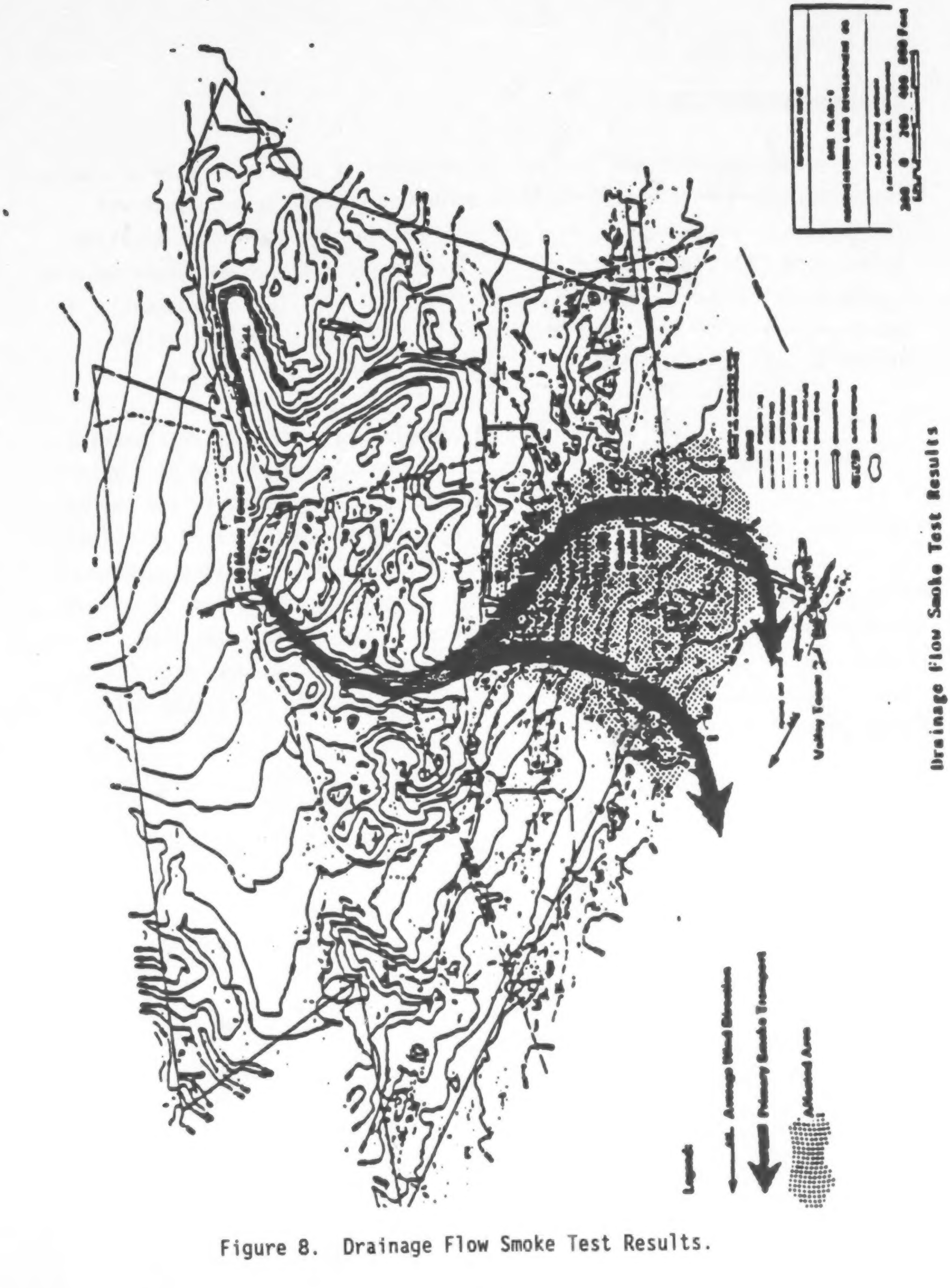
Drainage Flow Smoke Test Results
Legend
Average Wind Direction
Primary Smoke Transport
Affected Area
Valley Tower

Figure 8. Drainage Flow Smoke Test Results.

Reproduced from
best available copy.

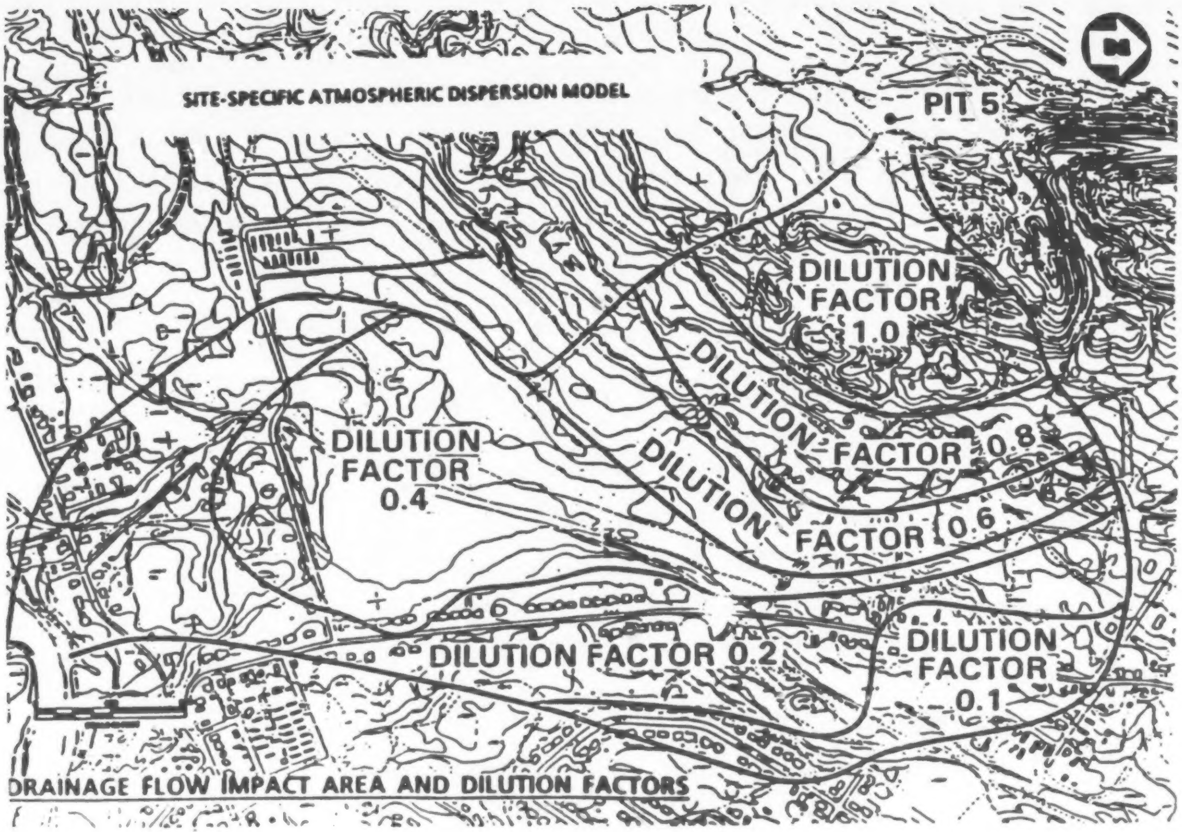
SITE-SPECIFIC ATMOSPHERIC DISPERSION MODEL
PIT 5
DILUTION FACTOR 1.0
DILUTION FACTOR 0.8
DILUTION FACTOR 0.6
DILUTION FACTOR 0.4
DILUTION FACTOR 0.2
DILUTION FACTOR 0.1
DRAINAGE FLOW IMPACT AREA AND DILUTION FACTORS

Figure 9. Drainage Flow Impact Area and Dilution Factors.

Supplemental analyses can be expensive and result in project schedule delays. Therefore, these analyses are generally only warranted if unacceptable offsite air pathway impacts have been predicted based on application of standard dispersion models and modeling procedures.

2.6.4 Prepare A Report

A report summarizing the results of the dispersion calculations should be prepared. It should include the elements of the modeling plan discussed in Section 2.4. These elements basically outline the overall methodology for the modeling. The following is a recommended outline for the report:

I Introduction

II Methodology
- Constituents To Be Modeled
- Emission Inventory
- Receptor Grid
- Detailed Modeling Methodology
- Estimated Background Concentrations

III Modeling Results
- Short- and Long-Term Concentrations
- Areas of Potential Impact
- Comparison with Applicable Air Toxics Guidelines

IV References

V Appendices
- Meteorological Data
- Emission Inventory
- Model Testing
- Detailed Modeling Printout

The report should include a sufficient amount of explanation of the methodology and results. Figures such as isopleths of concentrations are highly recommended. Voluminous data printouts are often not necessary if the data are carefully summarized and the full set of data provided on a floppy disk.

SECTION 3
AIR MONITORING PROCEDURES

3.1 OVERVIEW

Air monitoring is an air pathway analysis (APA) approach that can provide direct measurements of air contamination levels at receptor locations of interest. This approach is useful for checking modeling predictions and as part of the overall health and safety monitoring at Superfund sites. Air monitoring, however, is limited to existing sources. Also, monitoring methods with detection levels commensurate with health criteria may not be available for all contaminants of interest.

This section provides procedures for the selection and application of air monitoring approaches for Superfund APAs. The procedures are necessarily general so as to apply to any generic site, and they are as complete as possible so that potentially important considerations will not be overlooked for any specific site. Each consideration of the procedures will not be applicable for every site, nor will it always have an equal relative importance.

Recommendations concerning air monitoring applications for specific Superfund activities and sources have been presented in Volume I. These recommendations are cross-referenced and potential Superfund air monitoring applications are summarized in Table 11. A review of this information indicates that air monitoring applications are directly related to specific Superfund activities. Therefore, the technical information and recommendations in this section are frequently presented on a Superfund activity-specific basis.

TABLE 11. SUMMARY OF AIR MONITORING APPLICATIONS

Source Classification	APA Recommendations	Superfund Activities	Air Monitoring Applications
Pre-Remediation Source	Characterize baseline air concentrations	RI/FS - Screening/Refined Screening APA	• Preliminary baseline air quality data and information on emissions. • Air Quality Data in support of the design of a refined air monitoring program to support the RI/FS (i.e., preparation of site-specific Work Plan and Field Sampling and Analysis Plan).
Pre-Remediation Source	Characterize baseline air concentrations	RI/FS - Refined APA	• Comprehensive baseline air quality for on-site, perimeter, and off-site. • Data are used as risk assessment input for the no-action alternative. • Data are used in evaluating remedial alternative actions.

(Continued)

TABLE 11. (Continued)

Source Classification	APA Recommendations	Superfund Activities	Air Monitoring Applications
Remediation Source	Characterize air concentration during remedial/removal activities.	Remedial design (pilot field studies)	● Work area, perimeter, and off-site air monitoring program in support of pilot field studies. ● Data are used to assess worker exposures and estimate the effect on the public and the environment during the remedial action.
Remediation Source	Characterize air concentrations during remedial/removal activities.	Remedial actions (full-scale operations).	● Work area, perimeter, and off-site air monitoring program in support of clean-up activities. ● Data are used to protect workers, the public, and the environment under routine and non-routine air releases.
Post-Remediation Source	Confirm controlled source air concentrations.	Operation and Maintenance (post-remedial activities).	● Perimeter and off-site program to evaluate the performance of the remedial action. ● Data are used to verify the effectiveness of the remedial action in protecting public health and the environment.

The procedures for air monitoring presented in this section are based on a five-step process (illustrated in Figure 10):

- Step 1 - Collect and review input information;
- Step 2 - Select monitoring sophistication level;
- Step 3 - Develop monitoring plan;
- Step 4 - Conduct monitoring; and
- Step 5 - Summarize and evaluate results.

Each of these steps is briefly described below and discussed in more detail in subsequent subsections.

Step 1 - Collect and Review Input Information--Existing information pertinent to the air monitoring program should be collected. Possible sources of information include site files, EPA guidance documents, local meteorological stations, and the open literature. Available information should be obtained for emission sources, receptors, and historical meteorological trends. Once the existing data have been collected, compiled, and evaluated, data gaps can be defined and a coherent air monitoring plan developed based on the site-specific requirements.

Step 2 - Select Monitoring Sophistication Level--The air monitoring sophistication level should be selected from among screening, refined screening, and refined monitoring techniques. This selection process depends on program objectives as well as available resource and technical constraints. Technical aspects that should be considered include the availability of appropriate monitoring and analysis techniques for the toxic and hazardous compounds present at the site. Monitoring approaches should be evaluated considering compound-specific factors, including detection limits, performance criteria (e.g., precision, accuracy), and advantages and disadvantages of alternative methods.

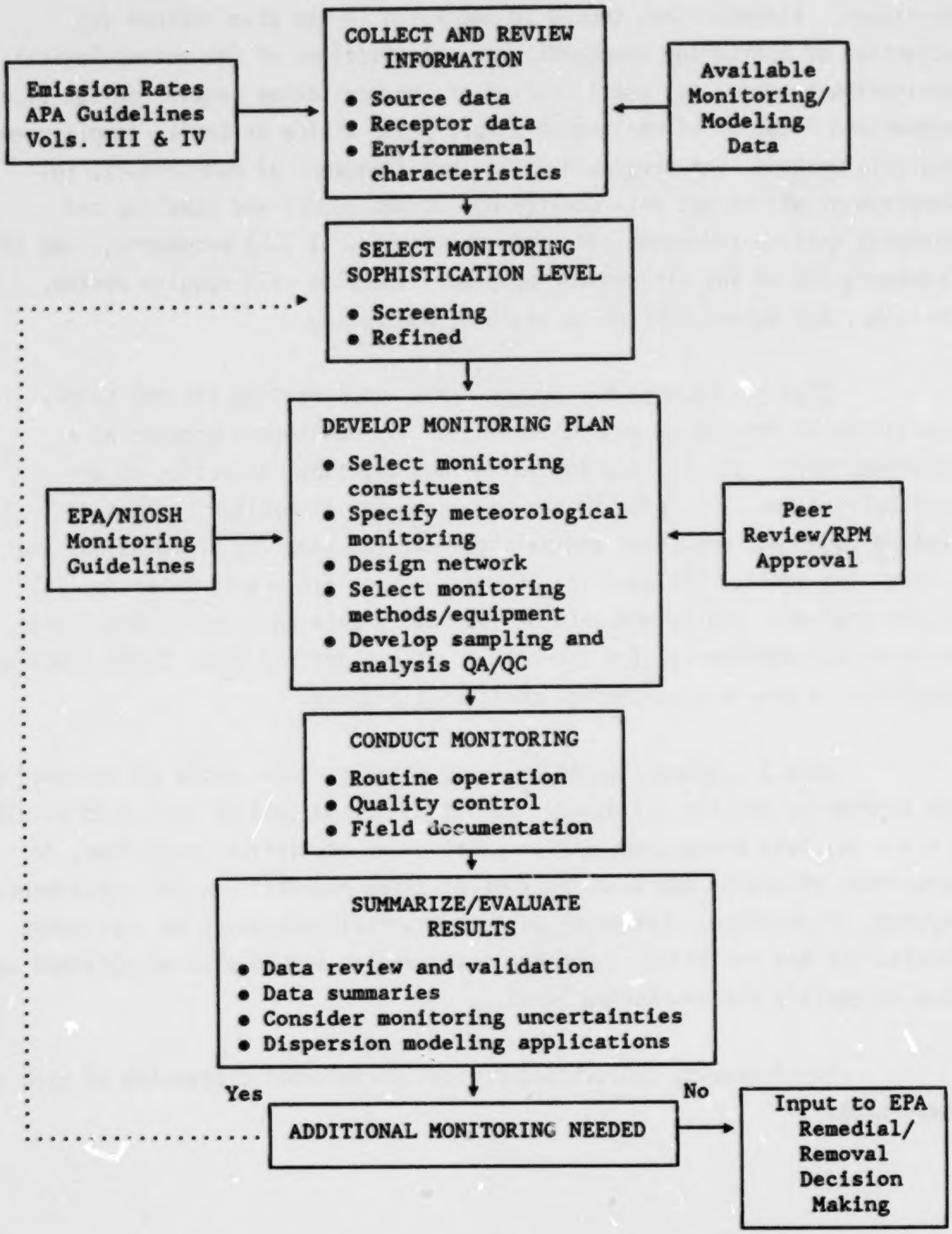
COLLECT AND REVIEW INFORMATION
• Source data
• Receptor data
• Environmental characteristics
Emission Rates APA Guidelines Vols. III & IV
Available Monitoring/ Modeling Data
SELECT MONITORING SOPHISTICATION LEVEL
• Screening
• Refined
DEVELOP MONITORING PLAN
• Select monitoring constituents
• Specify meteorological monitoring
• Design network
• Select monitoring methods/equipment
• Develop sampling and analysis QA/QC
EPA/NIOSH Monitoring Guidelines
Peer Review/RPM Approval
CONDUCT MONITORING
• Routine operation
• Quality control
• Field documentation
SUMMARIZE/EVALUATE RESULTS
• Data review and validation
• Data summaries
• Consider monitoring uncertainties
• Dispersion modeling applications
Yes
No
ADDITIONAL MONITORING NEEDED
Input to EPA Remedial/ Removal Decision Making

Figure 10. Superfund Air Pathway Analyses Air Monitoring Protocol.

Step 3 - Develop Monitoring Plan--An air monitoring plan should be developed. Elements that should be addressed in the plan include (a) selection of monitoring compounds, (b) specification of the meteorological monitoring program, (c) specification of the monitoring network design (i.e., number and location of monitoring sites, probe siting criteria, sampling and analysis methods, and program duration and frequency of monitoring), (d) development of project data quality objectives (DQOs) and sampling and analysis quality assurance (QA) and quality control (QC) procedures, and (e) documentation of the air monitoring plan. The plan will require review, revision, and approval prior to starting monitoring.

Step 4 - Conduct Monitoring--This step involves the day-to-day activities of initiating and conducting an air monitoring program at a Superfund site. It includes the following: (a) final selection of air monitoring sites, (b) installation and check-out of monitoring equipment, (c) routine equipment operation and maintenance, (d) sampling calibrations and checks, (e) audits, (f) handling of samples, (g) field documentation, (h) sample analysis, (i) maintenance of laboratory data and records (including chain-of-custody forms), (j) corrective action, and (k) other QA/QC procedures necessary to ensure a successful monitoring program.

Step 5 - Summarize and Evaluate Results--Data should be reviewed and air monitoring results validated. Additional components of this step should include (a) data processing, (b) preparation of statistical summaries, (c) comparison of upwind and downwind concentration results, and (d) concentration mapping, if possible. Estimates of data uncertainties based on instrument limitations and analytical technique inaccuracies should also be obtained and used to qualify air monitoring results.

The following subsections present an expanded discussion of each of these steps.

3.2 STEP 1 - COLLECT AND REVIEW INPUT INFORMATION

3.2.1 Overview

The first step in the design and implementation of an effective air quality monitoring program is the compilation and evaluation of available information. The following information, at a minimum, should be considered when developing an air monitoring program design:

- Source data;
- Receptor data;
- Environmental data; and
- Previous APA data.

Most of the site-specific information required for Step 1 is available from the Superfund remedial project manager/enforcement project manager (RPM/EPM). The quality of available information will depend on the nature and extent of the previously performed studies. In general, the quality of information should improve as the Superfund process progresses since each step can build on the results of previous work.

Available information and data should be evaluated for the following factors:

- Technical soundness of methodologies employed;
- Completeness and quality of the data, including detection limits, precision, and accuracy;
- Quality assurance/quality control results;
- Compatibility and applicability of the data; and
- Existence of data gaps.

The results of the evaluation should be documented using a form similar to the example presented in Table 12. In addition, copies of data summaries should be attached to the form to provide a convenient, complete documentation package for the project files.

The following subsections provide a further discussion of the various types of data that should be collected during Step 1.

3.2.2 Source Data

Site-specific information on the nature and extent of the in-situ contamination is essential for estimating the magnitude of air emissions from each of the source areas and in defining the primary airborne contaminants of interest. The data should be available from the Superfund RPM/EPM, though the data will be relatively incomplete or uncertain until the RI/FS work has been completed. Specific information that should be collected and evaluated includes:

- Specific source areas at the site and their estimated locations, configuration, and dimensions based on information about past contamination. (Example source areas are lagoons, drainage ditches, landfills, contaminated soil surfaces, drums, tank and container areas, and structures within processing facilities.);

- Contaminants associated with each source area. It will be useful to subdivide the contaminants into groups and subgroups with similar chemical or physical characteristics: organics (volatiles, semivolatiles, base neutrals, pesticides, PCBs) and inorganics (metals and other toxic compounds [e.g., H2S, HCN]);

- Toxicity factors important in evaluating the potential risk to human health and the environment; and

- Identification and description of offsite air emission sources.

TABLE 12. EXAMPLE - SUPERFUND AIR MONITRING PROGRAM INPUT INFORMATION FORM

	Data Obtained		Evaluation Factors					
Data Type	(Yes or No or N/A)	(Attachment #)	Technical Methods Employed Acceptable (Yes or No)	Completeness and Quality of Data Acceptable (Yes or No)	QA/QC Appropriate (Yes or No)	Data Relevant for this Application (Yes or No)	Data Gaps Significant (Yes or No)	Comments
Source Data								
• Site Layout Map								
• Contaminants List								
• Emission Inventory								
• Contaminant Toxicity Factors								
• Off-Site Sources								
Receptor Data:								
• Population Distribution Map								
• Identification of Sensitive Receptors								
• Site Work Zones Map								
• Local Land Use								
Environmental Data:								
• Dispersion Data								
- Wind Direction/ Wind Speed								
- Atmospheric Stability								
• Climatology								
- Temperature								
- Humidity								
- Precipitation								
• Topographic Maps								
- Site								
- Local Area								
• Soil and Vegetation								

(Continued)

TABLE 12. (Continued)

	Data Obtained		Evaluation Factors					
Data Type	(Yes or No or N/A)	(Attachment #)	Technical Methods Employed Acceptable (Yes or No)	Completeness and Quality of Data Acceptable (Yes or No)	QA/QC Appropriate (Yes or No)	Data Relevant for this Application (Yes or No)	Data Gaps Significant (Yes or No)	Comments
Previous APA Data:								
• Emission Rate Modeling								
• Emission Rate Monitoring								
• Dispersion Modeling								
• Air Monitoring								
• ARAR Summary								

3.2.3 Receptor Data

Receptor data, when coupled with source data, can provide the basis for a cost-effective air monitoring program design for a Superfund project. Receptor information that should be collected and evaluated includes the following:

- Results of air dispersion modeling showing locations of calculated high, ground-level concentrations of air toxics contaminants emitted from the site and from other nearby sources;
- Upwind and downwind receptor locations based on prevailing wind conditions at the site;
- Population distribution by 22.5-degree sectors in 1- to 2-kilometer increments for a distance of 10 kilometers from the site;
- Sensitive receptors within 10 kilometers of the site and individual residences and buildings within 1 to 2 kilometers of the site;
- Site work zones as identified in the Health and Safety Plan; and
- Local land use characterization (e.g., residential, commercial) within 10 kilometers of the site.

Sensitive receptor locations include schools, nursing homes, hospitals and other places associated with sensitive population segments, as well as locations with sensitive non-human receptors.

3.2.4 Environmental Characteristics

Existing information on the environmental characteristics pertinent to a Superfund site should be considered when defining air pathway exposure potential. Environmental characteristics data that may be relevant to the design of an air monitoring program include:

- Dispersion characterization data including wind direction/speed and atmospheric stability summaries;
- Climatological data representative of the site area, including wind, precipitation, temperature, and humidity conditions;
- Topographic features and water bodies at the site and vicinity;
- Soil and vegetation characteristics of the site and vicinity; and
- Any other environmental factors that could affect the number, location, and type of air monitoring stations.

Existing representative dispersion and climatological data will be useful in evaluating the numbers and locations of air monitoring stations. Wind data can be used for evaluating candidate upwind and downwind locations for air monitoring. Wind data, atmospheric stability, ambient temperature, and mixing height data can be used with an air dispersion model (see Section 2) to provide estimated calculated concentrations for the contaminants of interest at locations of maximum impact. Temperature, precipitation, and humidity data can influence the selection of monitoring and analysis methods.

Topographic features and water bodies can affect the dispersion and transport of airborne air toxic constituents. It is therefore important to understand local wind flows and to identify areas with topography and/or water bodies that can influence the dispersion and transport of constituents released from the site. For example, a site located downslope of an elevated terrain feature could be affected by nighttime downslope drainage flows. Topographic features should also be considered in siting air monitoring stations to avoid natural obstructions.

Large water bodies can affect atmospheric stability conditions and the dispersion of air contaminants. In general, large water bodies tend to increase the stability of the atmosphere in the air layer adjacent to the water, thus reducing the dispersion of air contaminants.

Soil characteristics and conditions can influence emission rates of volatile species from Superfund sites and have a large impact on the wind erosion of contaminated surface soils. It is important when considering particulate matter emissions to understand soil conditions such as porosity, particle size distribution, soil type, and source data.

Vegetation, including shrubs and trees, can be a factor in siting an air monitoring station due to flow obstructions and accessibility. In addition, vegetation can retard emissions of subsurface contaminants and can affect air flow because of the increase in surface roughness.

3.2.5 Previous APA Data

The Superfund APA recommendations presented in Volume I specify conducting of emission rate modeling/monitoring and dispersion modeling as a prerequisite to an air monitoring study. Therefore, the following data should be available from previous APAs and should be collected and reviewed:

- Onsite meteorological monitoring data;
- Emission rate modeling data;

- Emission rate monitoring data;
- Dispersion modeling data;
- Air monitoring data; and
- Applicable or relevant and appropriate requirements (ARAR) summaries that identify air toxic exposure criteria.

These APA data are significant input to development of a site-specific air monitoring program. If these types of data are not available or do not meet completeness or QA/QC specifications, then it is recommended that site-specific and source-specific APAs be conducted to estimate emission rates and air concentrations (via dispersion modeling) to provide these inputs. Overall recommendations on developing APA data are specified in Volume I. Procedures for characterizing baseline air emissions from Superfund sources are presented in Volume II, and procedures for characterizing air emissions from remedial actions are available in Volume III. Procedures for the conduct of dispersion modeling studies to support Superfund APAs are presented in Section 2 of this document. ARARs are discussed in Volume I.

Previous air quality data available for the site area that address air concentrations of contaminants known to exist at the site can provide insight on the existing levels of air toxic constituents of interest. Compound-specific information will be useful in assessing what indicator compounds should be monitored and what monitoring and analysis methodologies should be employed.

Existing air quality data should be evaluated for acceptable quantity, quality, and representativeness before use. Factors to be accounted for in these evaluations include:

- Monitoring and analysis techniques employed during the air monitoring program. These include the type of techniques (screening, refined screening, or refined monitoring), associated detection limits, accuracy, and precision for the constituents monitored.

- Number and types of compounds that were monitored and analyzed. This information is important to determine the degree of interference between the compounds involved; this often limits the usefulness of nonspecific compound screening analysis procedures, since the response from background compounds may overwhelm any response because of small levels of the compounds of interest.

- Records about equipment performance, maintenance, and calibration.

- Records of audits performed to evaluate program quality.

- Detailed description of the monitoring station setting to allow for an evaluation of the station siting. Consideration should be given to siting criteria such as proper sample intake exposure, proper height above ground, and avoidance of man-made and natural obstructions that could affect or alter the air flow near the sampler intake.

Existing air dispersion modeling for the site area can be useful in evaluating locations for ambient air monitoring stations. Coupled with measured air quality data, results of air dispersion modeling offer an objective means for siting air quality monitoring stations at locations of maximum impact. Data available from air dispersion calculations can be used as input into the risk assessment, which can in turn be used in selecting locations of sensitive receptors. Procedures for the conduct of dispersion modeling were presented in Section 2.

3.3 STEP 2 - SELECT MONITORING SOPHISTICATION LEVEL

3.3.1 Overview

The selection of air monitoring sophistication levels, including associated sampling and analytical methods, is the cornerstone of a successful air monitoring program. The three levels of sophistication described in this section are screening, refined screening, and refined monitoring. The appropriate monitoring sophistication level for each Superfund project application depends on the following factors:

- Source-specific APA recommendations (presented in Volume I);
- Input data from Step 1 (Table 12);
- Technical air monitoring objectives (Table 13);
- Overall project objectives and activity-specific air monitoring applications (Table 13);
- Legal and liability aspects of the Superfund project; and
- Pragmatic aspects of the program
  - Duration of the monitoring program
  - Time to obtain results
  - Technical expertise of field personnel
  - Ability to accomplish the air monitoring program objectives by obtaining good quality data with modest uncertainties.

Of these factors, the time to obtain results (analytical turnaround time) dictated by the program objectives is often the single most important criteria when selecting from among air monitoring approaches.

TABLE 13. SUMMARY OF TECHNICAL AIR MONITORING OBJECTIVES

Superfund Activity	Technical Air Monitoring Objective
RI/FS - Screening APA	• Provide preliminary insight about the existence of air emissions and their characteristics (magnitude of air concentraitons, constituents involved and their distribution) by performing on-site measurements. • Provide preliminary air quality baseline (on-site and perimeter). • Provide preliminary information for on-site exposure (workers), perimeter and off-site exposure (population and the environment) under existing conditions. • Provide air quality data in support of the design of a good air monitoring program under the RI/FS step, including components of the Health and Safety Plan.
RI/FS - Refined APA	• Provide detailed insight about the existence of air emissions and their characteristics (magnitude of emissions, constituents involved and their distribution) by perfoming on-site measurements. • Provide on-site air quality data during the field investigations in support of the Work Plan, Field Sampling and Analyses Plan and Health and Safety Plan to protect the field team. • Provide sufficient data base for perfroming a detailed risk assessment of the public and the environment based on on-site pereimter, and off-site air quality data under the baseline conditions (no-action alternative). • Provide sufficient data base for performing the evaluation of remedial alternatives. • Provide ground truth to dispersion modeling calculations.

(Continued)

TABLE 13. (Continued)

Superfund Activity	Technical Air Monitoring Objective
Remedial Design (field demonstration)	• Provide on-site air quality data during the implementation of field pilot studies in support of the Health and Safety Plan for this step to protect on-site workers. • Provide perimeter air quality data for preliminary assessment of the effects of the remedial action evaluated.
Remedial Action	• Provide work area air quality data for routine and non-routine air releases to protect workers and to provide a guidance for anticipated air concentration at site perimeter and off-site. • Provide work area air quality data in support of an emergency response air dispersion model and APA emergency field guide (see Appendix C). • Provide perimeter and off-site air quality data in support of an emergency response air dispersion model. • Provide work area, perimeter, and off-site air quality data in support of protective actions during the remedial action activities.
Operation and Maintenance	• Provide a long-term air quality database at the site perimeter and off-site as a part of assessing the effectiveness of the remedial action implemented. • Provide a long-term air quality database at the site perimeter and off-site to demonstrate the protection of public health and the environment.

Source-specific APA recommendations have been presented in Volume I. The APA strategy assumes that an initial screening APA should be conducted. This screening work serves as one input for deciding when more refined air monitoring work will be required. The dominant considerations, however, for selecting the monitoring sophistication level are the ambient levels of specific contaminants expected at the site. These data can be generated by applying emission rate models to the known site and waste characteristics. These emission rates are then used as input to dispersion models to predict the concentration levels at receptor locations of concern, and these levels are in turn compared to health-based action levels. The greater the liklihood for exceedances of the action levels, the greater the need for more refined air monitoring data.

Sophistication level recommendations presented in Table 11 should be evaluated based on site-specific factors. For example, input data collected during Step 1 may include previous air monitoring results. Therefore, these data may provide sufficient information to preclude the need for screening monitoring, although refined monitoring may still be warranted.

The air monitoring objectives for specific Superfund activities (e.g., RI/FS, remedial action) are the single important input for the selection of monitoring sophistication levels. These activity-specific objectives are summarized in Table 16. Input from the RPM/EPM should be obtained to confirm site-specific air monitoring objectives and to ensure that the air monitoring level selected is consistent with these objectives.

The availability of appropriate monitoring methods is another significant factor for monitoring sophistication level decision-making. Certain compounds, polychlorinated biphenyls (PCBs) for example, are not conducive to screening monitoring. A further discussion of available monitoring methods is presented in Section 3.4. It is also necessary to consider the uncertainty associated with the monitoring results.

3.3.2 Definition of Monitoring Sophistication Levels

Alternative monitoring sophistication levels for Superfund APA applications can be classified as follows:

- Screening level
    - Screening techniques
    - Refined screening techniques; and

- Refined level
    - Refined techniques.

Screening techniques are generally associated with relatively high detection levels (i.e., in the range of parts per million for gaseous contaminants and milligrams per cubic meter for particulate matter commensurate with industrial hygiene measurements) and frequently are used to provide real-time results in the field. Quite often, these detection levels exceed health criteria and ARARs. Screening techniques are also quite limited regarding the number of constituents that can be evaluated concurrently. Therefore, screening techniques are most effective for monitoring near the source to confirm the presence of an air release and for providing input information to support the development of specifications for a more refined monitoring program. It is important to recognize that monitoring screening techniques are not inherently conservative; therefore, the absence of air concentrations measured in a screening mode does not mean that air impacts are entirely absent.

Candidate screening techniques are summarized in Table 14. The screening techniques for gaseous constituents presented in Table 14 include total hydrocarbon (THC) analyzers, colorimetric gas detection tubes, electrochemical alarm cells, and screening portable gas chromatograph (GC) analyzers. Screening portable GC analyzers are available that provide gross information on the concentration of an individual air toxic constituent.

TABLE 14. AN OVERVIEW OF SCREENING AIR MONITORING/SAMPLING TECHNIQUES

Program Sophistication Level	Category of Monitoring/Sampling Method	Detection Limit	Compounds Detected	Monitoring/Sampling Mode	Typical Uncertainty Factors
Screening	**Gas Phase:** • Total hydrocarbon (THC) analyzers.	• ppm	• Most organics but not by chemical species.	• Realtime-continuous	±50-200%
Screening	• Colorimetric gas detection tubes and monitors.	• ppm	• Various organics and in-organics for a specific chemical species.	• Historical-integrated	±50-200%
Screening	• Electrochemical alarm cells	• ppm	• Various organics for a specific chemical species.	• Realtime-continuous	±50-200%
Screening	• Screening portable GC analyzer	• ppb	• Species expressed as equivalent to a selected single species.	• Realtime-continuous	±50-200%
Screening	**Particulate Phase:** • Portable pumps with filters.	• mg/m^3	• Most inorganic compounds	• Historical-integrated	±50-100%
Screening	• Portable pumps with filters and special plugs.	• mg/m^3	• Semi-volatile chemical species.	• Historical-integrated	±50-100%
Screening	• Portable aerosol monitor.	• mg/m^3	• Total suspended particulates (TSP).	• Realtime-continuous	±50-100%
Refined screening	**Gas Phase:** • Portable field GC analyzers with constant-temperature oven.	• ppb	• Limited list of organic compounds by chemical species.	• Realtime-continuous	±100%
Refined Screening	• Field GC laboratory	• ppb	• Limited list of organic compounds by chemical species.	• Historical-integrated	±100%

Screening techniques applicable to particulate matter include portable pumps with special filters or plugs and portable monitors that detect changes in light absorbance.

Table 14 includes uncertainty values (UF) that typify the deviation from a perfect method (i.e. a method with an uncertainty factor of ±1.0). An uncertainty of ±3.0 means a deviation of ±200 percent from the "true" value can be expected.

The typical uncertainty values are based on a qualitative assessment of the various screening methods, experience, and field applications. The uncertainty values depend on the number of the air toxic compounds involved, the concentration of the individual compounds, and the interferences introduced.

Refined screening techniques can provide reasonably accurate information on ambient air quality of organic compounds in the gas phase at the ppb level. These refined screening techniques utilize a combination of air sampling and a near-real-time analytical analysis without the use of offsite laboratory facilities. Refined screening air monitoring techniques listed in Table 14 include field portable GC systems.

Although similar to the refined methods discussed below, refined screening techniques have the following relative limitations as compared to the more sophisticated refined methods:

- The target analyte list is more limited;
- Only uncomplicated matrices of chemical species can be analyzed; and
- QA/QC procedures are less comprehensive than those used by a certified offsite laboratory.

Refined air monitoring is applicable to situations where high-quality data are required and immediate response time for obtaining air quality results is not required. It also is applicable as a supplement to the near-real-time air monitoring data obtained through the use of a refined screening technique during the implementation of remedial actions. In such a case, the refined air monitoring technique provides high-quality results to supplement and verify results of the refined screening monitoring. Of course, the comparison between the two is based on historical data.

A listing of typical refined air monitoring techniques is presented in Table 15. A myriad of refined air monitoring techniques is available, and the process of selecting the most suitable one can be difficult. This is because of the technical limitations of available monitoring methods and the large number of target compounds that may be involved. Furthermore, the field of air toxics monitoring is still undergoing rapid development.

In spite of the high quality of the chemical analyses involved with refined air monitoring techniques, it is possible that the data obtained will be useful only in a qualitative rather than a quantitative way. The reasons for this could be many. Several factors that could affect the quality of the data include the following:

- Large number of compounds involved;
- Variability in the concentrations of individual compounds and the need for low detection limits;
- Potential for the formation of artifacts during sampling;
- Interference between compounds during analysis; and
- Variable response of the analytical system as a function of the specific compound.

TABLE 15. AN OVERVIEW OF REFINED AIR MONITORING/SAMPLING TECHNIQUES

Program Sophistication Level	Category of Monitoring/Sampling Method	Detection Limit	Compounds Detected	Monitoring/Sampling Mode	Typical Uncertainty Factors
Refined	**Gas Phase:** • Traps (sorbents and cryogenics) and laboratory analysis.	• Fraction of a ppb to ppb.	• Many organic compounds by chemical species.	• Historical-integrated	±100%
	• Whole air samplers (bags and canisters) and laboratory analysis.	• Fraction of a ppb to ppb.	• Many organic compounds by chemical species.	• Historical-integrated	±50%
	• Liquid impingers	• Fraction of a ppb to ppb.	• Aldehydes, ketones, phosgene, cresol/phenols.	• Historical-integrated	±100%
Refined	**Particulate Phase:** • High-Volume samplers with glass fiber filter, membrane filter or teflon filter.	• μg/m^3	• Inorganics	• Historical-integrated	±50%
	• High-volume samplers with glass fiber filter and polyurethane foam[a]	μg/m^3	• PCBs and other semi-volatile organic species.	• Historical-integrated	±100%

[a] Polyurethane foam (PUF) plug is designed to collect semi-volatile organic gases.

This implies that a cost-benefit assessment may be useful. In many cases, a combination of sophistication levels will be appropriate.

An expanded discussion of alternative screening and refined air monitoring methods/equipment is presented in Section 3.4.

3.4 STEP 3 - DEVELOP MONITORING PLAN

3.4.1 Overview

An air monitoring plan should be developed for each Superfund APA application. The objective of the plan is to document the Technical Specifications for a site/source-specific monitoring program. The plan also provides an opportunity for peer review and RPM/EPM approval of the monitoring program. Developing a site/source-specific monitoring plan involves the following major elements, as illustrated in Figure 11:

- Select monitoring constituents;
- Specify meteorological monitoring program;
- Design air monitoring network; and
- Document air monitoring plan.

Major input to the development of an air monitoring plan should include the information collected during Step 1 (e.g., identification of previous APAs, ARARs), the target compound list for monitoring developed during Step 2, and available EPA technical guidance.

Procedures for the development of an air monitoring plan are provided in the subsections that follow.

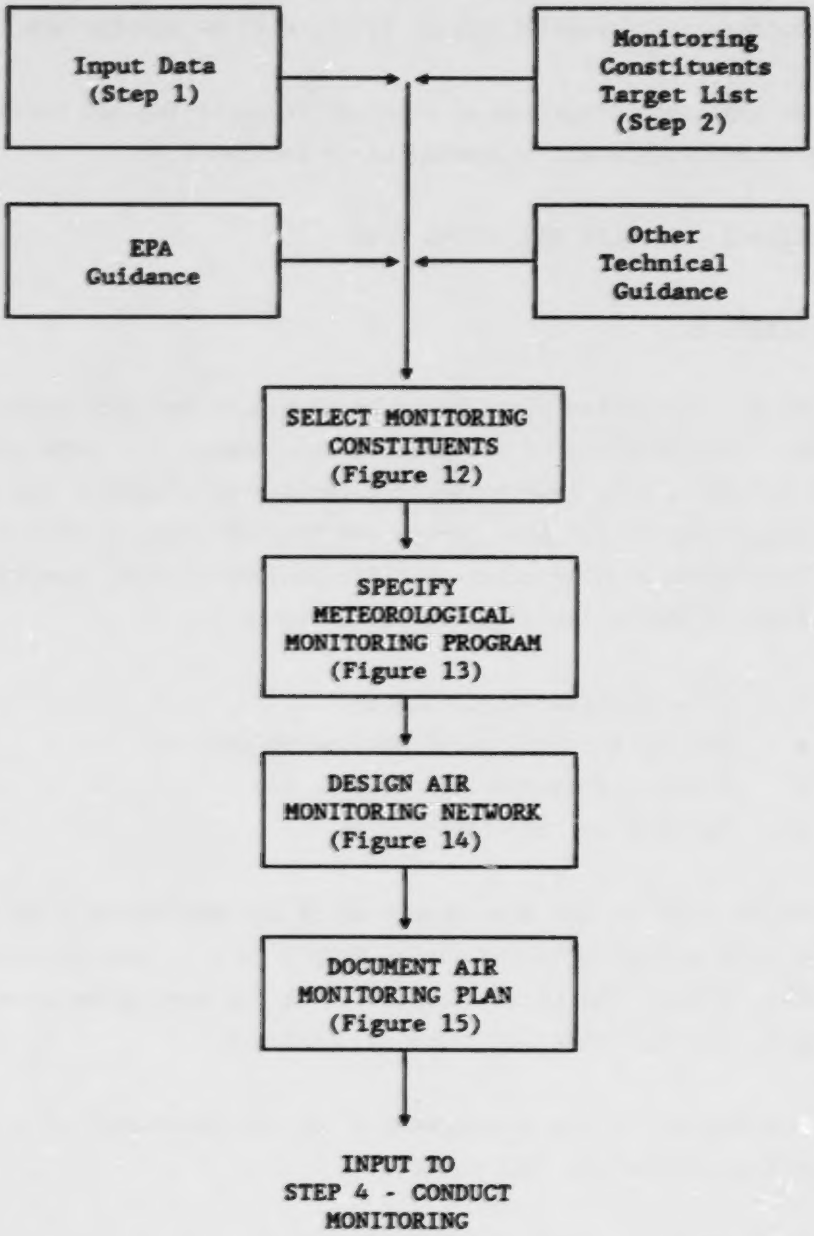
Input Data
(Step 1)
Monitoring
Constituents
Target List
(Step 2)
EPA
Guidance
Other
Technical
Guidance
SELECT MONITORING
CONSTITUENTS
(Figure 12)
SPECIFY
METEOROLOGICAL
MONITORING PROGRAM
(Figure 13)
DESIGN AIR
MONITORING NETWORK
(Figure 14)
DOCUMENT AIR
MONITORING PLAN
(Figure 15)
INPUT TO
STEP 4 - CONDUCT
MONITORING

Figure 11. Step 3 - Develop Monitoring Plan.

3.4.2 Select Monitoring Constituents

The selection of compounds to be addressed in the monitoring program is a challenging task for Superfund applications because of the extensive number of potential release contaminants. Sampling/analytical technical factors and project budget limitations generally necessitate the selection of a limited subset of target compounds. The selection of target air monitoring contaminants involves the following key factors:

- Physical and chemical properties of the constituents
  - Physical phase (gas, particulate)
  - Volatility
  - Water solubility
  - Etcetera
- Toxicity and health effects (risk assessment) of the chemicals involved;
- Estimated concentration of a constituent relative to other constituents and potential interference;
- Availability of standard sampling and analysis methods and their performance;
- Overall and technical project objectives; and
- Data quality objectives and resource constraints.

A list of the compounds included in the Hazardous Substances List (HSL) developed by EPA for the Superfund program was presented in Table 9. This list is a composite of the Target Compound List (TCL) for organics and the Target Analyte List (TAL) for inorganics. Table 9 also includes examples for additional potential Superfund air emission constituents (e.g., HCN, H2S, HCl). Therefore, Table 9 represents a comprehensive list of compounds from which a list of target air toxics compounds can be selected.

Emission rate measurement or modeling results should be obtained prior to the conduct of air monitoring studies based on Volume I recommendations. These results as well as air monitoring data (as available) should be used to identify appropriate site- and source-specific monitoring compounds from Table 9. Contaminants included in ARARs identified during Step 1 should also be used to identify target (i.e. indicator) compounds for air monitoring.

The limited set of target compounds based on previous APAs and ARAR considerations should be ratioed to the appropriate health-based action level to derive a hazard index (HI). The HI values computed should then be ranked from highest to lowest in order to develop a priority list of candidate target compounds. The final compounds selected for air monitoring should be a function of the APA sophistication level and the technical feasability of collecting and analyzing the various compounds. A flowchart to assist in selection is given as Figure 12.

For screening applications, one to five target compounds with the highest HI values for which appropriate monitoring methods are available should be selected. Target compounds could include total hydrocarbons for organics and compound class indicators (e.g., ethers, aromatics) for organics and inorganics. Specific organic and inorganic contaminantss could also be selected.

Refined screening monitoring applications should include the selection of 5 to 10 target compounds with the highest HI values. This approach should facilitate the preliminary characterization of air releases at Superfund sites. Again, the selection process should consider the availability of appropriate monitoring methods commensurate with health and safety criteria.

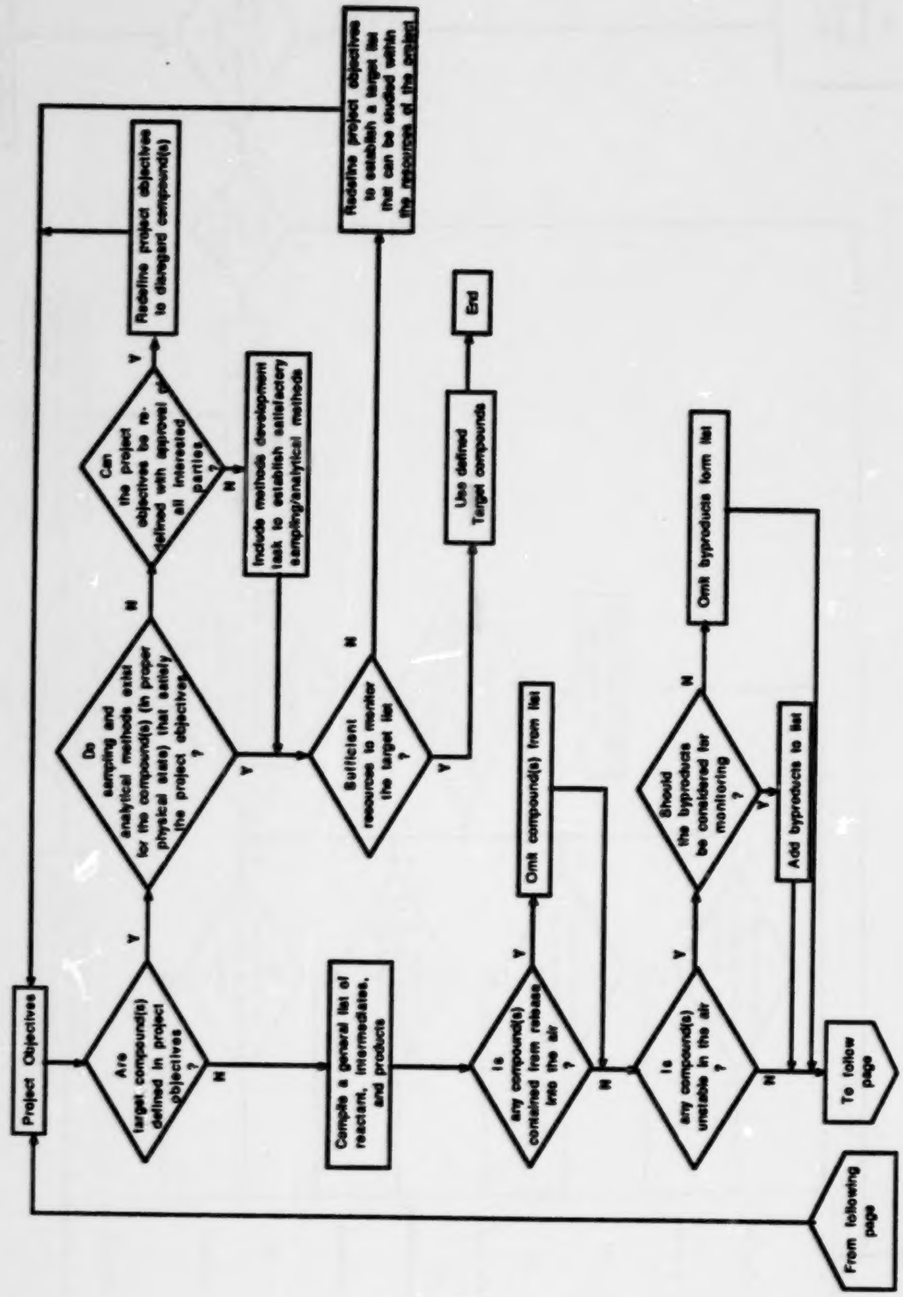
Project Objectives
Are target compound(s) defined in project objectives ?
Y
N
Do sampling and analytical methods exist for the compound(s) (in proper physical state) that satisfy the project objectives ?
Y
N
Can the project objectives be re-defined with approval of all interested parties ?
Y
N
Redefine project objectives to disregard compound(s)
Include methods development task to establish satisfactory sampling/analytical methods
Sufficient resources to monitor the target list ?
Y
N
Redefine project objectives to establish a target list that can be studied within the resources of the project
Use defined Target compounds
End
Compile a general list of reactant, intermediates, and products
Is any compound(s) contained from release into the air ?
Y
N
Omit compound(s) from list
Is any compound(s) unstable in the air ?
Y
N
Should the byproducts be considered for monitoring ?
Y
N
Omit byproducts form list
Add byproducts to list
To follow page
From following page

Figure 12. Flowchart for Defining a Target List of Compounds for Air Monitoring.

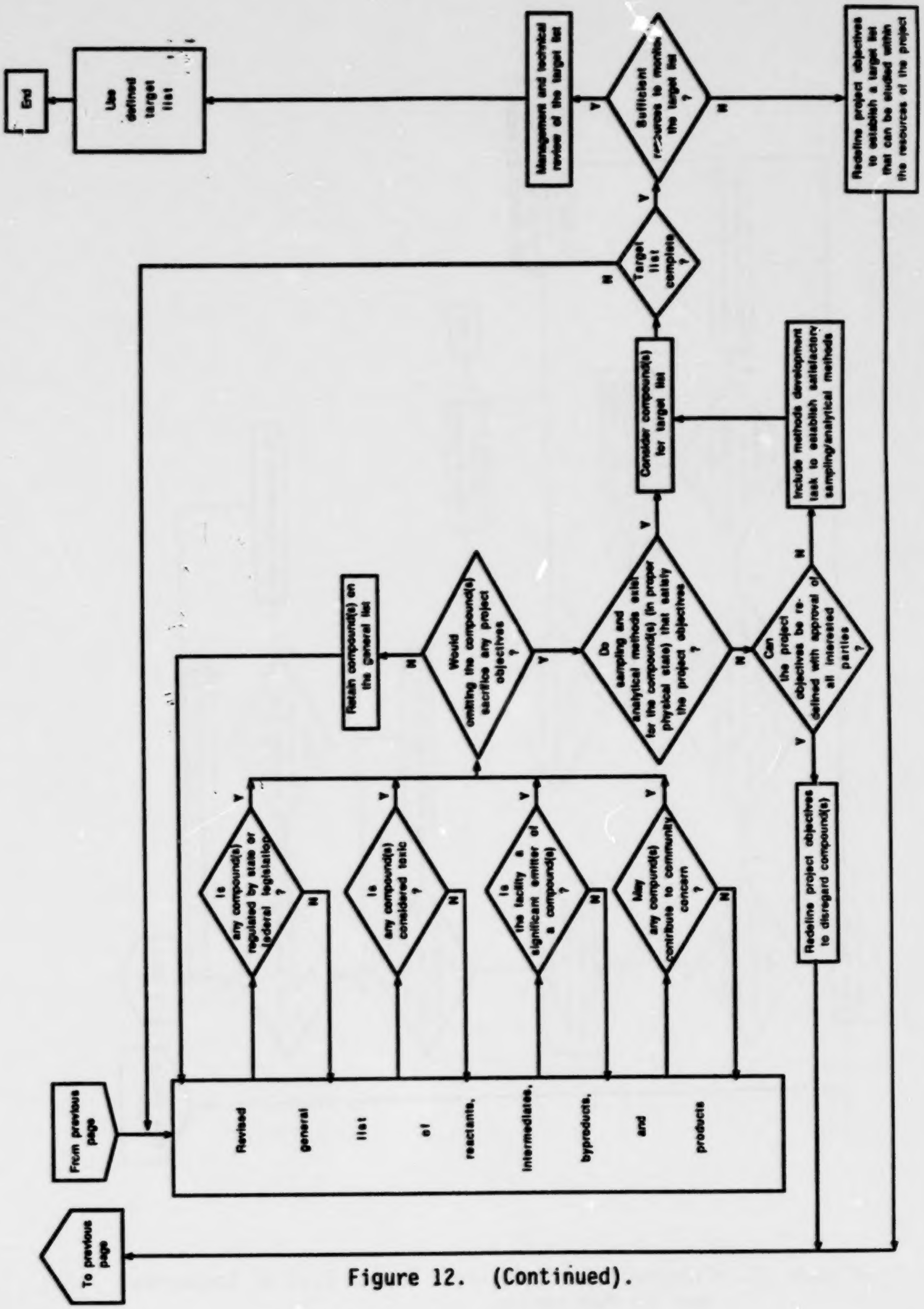
From previous page
Revised general list of reactants, intermediates, byproducts, and products
Is any compound(s) regulated by state or federal legislation ?
Is any compound(s) considered toxic ?
Is the facility a significant emitter of a compound(s) ?
May any compound(s) contribute to community concern ?
Y
N
Would omitting the compound(s) sacrifice any project objectives ?
Retain compound(s) on the general list
Do sampling and analytical methods exist for the compound(s) (in proper physical state) that satisfy the project objectives ?
Can the project objectives be redefined with approval of all interested parties ?
Redefine project objectives to disregard compound(s)
Include methods development task to establish satisfactory sampling/analytical methods
Consider compound(s) for target list
Target list complete ?
Management and technical review of the target list
Sufficient resources to monitor the target list ?
Use defined target list
End
Redefine project objectives to establish a target list that can be studied within the resources of the project
To previous page

Figure 12. (Continued).

Target compounds for refined APA monitoring should include all contaminants with an HI value greater than or equal to 10 percent of the composite HI value for the total mix. These contaminants are expected to represent the greatest contributors to potential health impacts.

The target compound list should be periodically reevaluated, and revised if warranted, as monitoring results become available. This is particularly useful for refined monitoring studies that are long term in nature (e.g., during remedial actions). For these applications it may also be effective to periodically (e.g., monthly) sample and analyze for a more comprehensive list of compounds to confirm the representativeness of the routine target compound list.

3.4.3 Specify Meteorological Program

A meteorological monitoring program should be an integral part of Superfund air monitoring activities. A meteorological survey can be used to design the air monitoring network based on local wind patterns. Meteorological and air quality data collected can be used for the interpretation of air concentration data considering upwind/downwind exposure conditions. A recommended procedure for the development of a site-specific meteorological program design is presented in Figure 13.

The number and location of meteorological stations needed for a site-specific application depend on local terrain conditions. One meteorological station is generally sufficient for flat-terrain sites. However, for complex-terrain sites it may be necessary to have multiple stations to represent major onsite/local air flow paths. Generally, one to three stations will be sufficient for these sites. To ensure a representative exposure, it is recommended that the meteorological stations be located away from any nearby obstruction at a distance equal to at least 10 times the height of the obstruction.

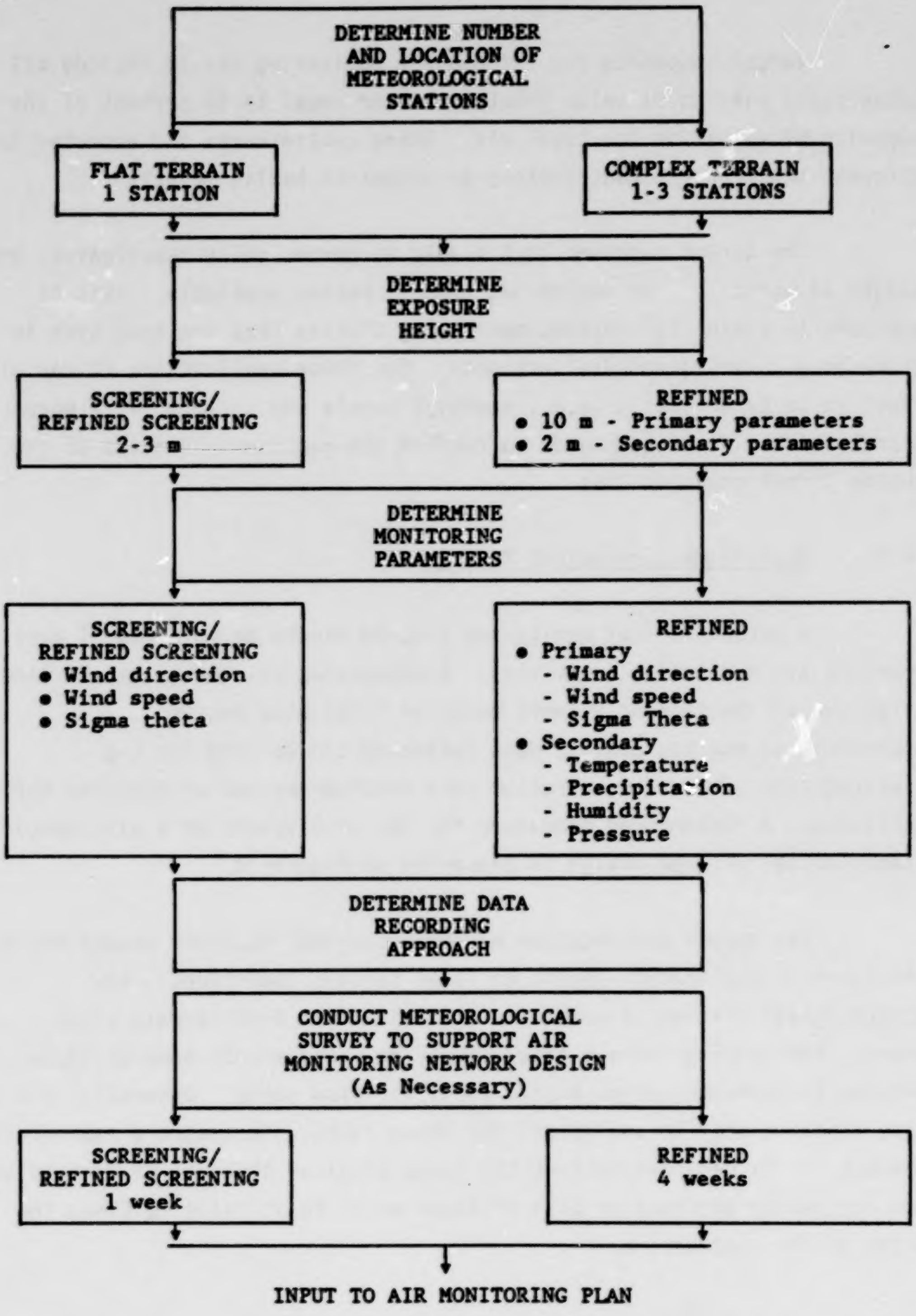
DETERMINE NUMBER AND LOCATION OF METEOROLOGICAL STATIONS
FLAT TERRAIN 1 STATION
COMPLEX TERRAIN 1-3 STATIONS
DETERMINE EXPOSURE HEIGHT
SCREENING/ REFINED SCREENING 2-3 m
REFINED
• 10 m - Primary parameters
• 2 m - Secondary parameters
DETERMINE MONITORING PARAMETERS
SCREENING/ REFINED SCREENING
• Wind direction
• Wind speed
• Sigma theta
REFINED
• Primary
- Wind direction
- Wind speed
- Sigma Theta
• Secondary
- Temperature
- Precipitation
- Humidity
- Pressure
DETERMINE DATA RECORDING APPROACH
CONDUCT METEOROLOGICAL SURVEY TO SUPPORT AIR MONITORING NETWORK DESIGN (As Necessary)
SCREENING/ REFINED SCREENING 1 week
REFINED 4 weeks
INPUT TO AIR MONITORING PLAN

Figure 13. Specify Meterological Monitoring Program.

Meteorological sensor exposure height should be 2-3 meters above the ground surface for screening and refined screening applications. This approach facilitates the use of portable stations, which can be rapidly deployed. For refined analyses the primary exposure height should be 10 meters (for wind and stability data) and 2 meters for parameters that do not directly affect atmospheric dispersion. For elevated releases such as those from incinerators, primary meteorological parameters should also be measured at stack height to the extent practicable.

Meteorological monitoring parameters for Superfund applications can be classified as follows:

- Primary parameters
  - Wind direction
  - Wind speed
  - Sigma theta (i.e., the horizontal wind direction standard deviation, which is an indicator of atmospheric stability)

- Secondary parameters
  - Temperature
  - Precipitation
  - Humidity
  - Atmospheric pressure

Primary parameters are representative of site dispersion conditions and should be included in all meteorological monitoring programs. Secondary parameters are representative of emission conditions and are generally only recommended for refined air monitoring activities.

Recommended meteorological monitoring system accuracies/resolutions and sensor response characteristics are summarized in Tables 16 and 17, respectively. Field equipment used to collect meteorological data can range in complexity from very simple analog or mechanical pulse counter systems to microprocessor-based systems. A combination of these approaches is recommended for Superfund applications. This approach is generally not expensive but it facilitates the convenient collection of meteorological data that can be processed onsite at a field office using personal computers (PCs). The chart recorders provide a low-cost backup system if the digital data are not available.

A meteorological survey should also be conducted to support air monitoring network design. Exceptions would include sites that have historical on-site meteorological data that are consistent with the DQOs or flat-terrain sites for which representative offsite data are available. The duration of the meteorological survey should range from 1 week for screening/refined screening applications to 4 or more weeks for the conduct of a refined air monitoring program. The survey should be conducted during a period (season and time of day) representative of the planned air monitoring program and air emission source operational schedules. However, it may be necessary to use historical offsite data to estimate seasonal effects for planning purposes if the air monitoring program is scheduled to last for more than a few months.

Additional recommendations on meteorological measurements can be obtained from the following sources:

- U.S. EPA. June 1987. On-Site Meteorological Program Guidance for Regulatory Modeling Applications. EPA-450/4-87-013. Office of Air Quality Planning and Standards. Research Triangle Park, NC 27711.

TABLE 16. RECOMMENDED SYSTEM ACCURACIES AND RESOLUTIONS

Meteorological Variable	System Accuracy	Measurement Resolution
Wind Speed	±(0.2 m/s + 5% of observed	0.1 m/s
Wind Direction	±5 degrees	1 degree
Ambient Temperature	±0.5°C	0.1°C
Dew Point Temperature	±1.5°C	0.1°C
Precipitation	±10% of observed	0.3 mm
Pressure	±3 mb (0.3 kPa)	0.5 mb
Time	±5 minutes	---

TABLE 17. RECOMMENDED RESPONSE CHARACTERISTICS FOR METEOROLOGICAL SENSORS

Meteorological Variable	Sensor Specification(s)[a]
Wind Speed	Starting speed ≤0.5 m/s; Distance constant ≤5 m.
Wind Direction	Starting speed ≤0.5 m/s at 10° deflection; Damping Ratio 0.4 to 0.7; Delay distance ≤5 m.
Temperature	Time Constant ≤1 minute.
Dew Point Temperature	Time Constant ≤30 minutes; operating temperature range -30°C to +30°C.

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[a] From Table 5-2. On-Site Meteorological Program Guidance for Regulatory Modeling Applications, U.S. EPA, Office of Air Quality Planning and Standards, Research Triangle Park, NC 27711. June 1987.

- U.S. EPA. February 1983. Quality Assurance Handbook for Air Pollution Measurements Systems: Volume IV, Meteorological Measurements. EPA-600/4-82-060. Office of Research and Development. Research Triangle Park, NC 27711.

- U.S. EPA. July 1986. Guidelines on Air Quality Models (Revised). EPA-405/2-78-027R. NTIS PB 86-245248. Office of Air Quality Planning and Standards. Research Triangle Park, NC 27711.

- U.S. EPA. May 1987. Ambient Monitoring Guidelines for Prevention of Significant Deterioration (PSD). EPA-450/4-87/007. Office of Air Quality Planning and Standards. Research Triangle Park, NC 27711.

3.4.4 Design Monitoring Network

The air monitoring network design will be affected by factors such as site-specific source, receptor, and environmental characteristics (see Table 18). Therefore, the design of an air monitoring network for a Superfund APA must be decided on a case-by-case basis. A recommended procedure for designing an air monitoring network is presented in Figure 14. Key components of the monitoring network design include:

- Number of locations of monitoring stations;
- Probe siting criteria;
- Program duration and frequency of monitoring;
- Sampling and analysis methods; and
- Air monitoring equipment.

Each of these components is discussed below.

TABLE 18. FACTORS AND ASSOCIATED ELEMENTS THAT AFFECT THE DESIGN OF AIR MONITORING PROGRAMS FOR SUPERFUND APAs

Factor	Elements
Technical air monitoring objectives	See Table 12
Source Characteristics	• Nature and extent of site sources (lagoon, landfarm, land disposal, processing facility, tank farm, etc) and their size. • Constituents involved and their physical state (gas, particle, total). • Estimated emission rates (measured or calculated). • Site source grouping.
Receptor Data	• Historical air quality data for the site area representing on-site, perimeter, and off-site measurements and the quality of the data. • Results of air dispersion modeling and locations of high calculated air toxics concentrations. • Number and locations of sensitive receptors (population; sensitive population locations-schools, hospitals, etc.; sensitive environmental species and settings such as flora and auna, state parks, and monuments, national parks and monuments, etc.) and distance to these locations.
Environmental Characteristic	• Historical records of meteorological data representing the site area including diffusion climatology and special conditions conducive to high concentration of airborne contaminants. • Topography in the site ara and its potential effect on local dispersion conditions, and its proximity to the site. • Water bodies in the site area, number, size and proximity to the site.
Data Quality Objectives	• Database for worker protection only. • Database for worker, public and environmental protection. • Laboratory turn-around time. • Detection limit for constituents involved. • Precision and accuracy of monitoring and analyses methodologies.

(Continued)

TABLE 18. (Continued)

Factor	Elements
Data Quality Objectives (Continued)	• Data representativeness. • Data completeness. • Data comparability. • Data use for Superfund APA application. • Frequency of monitoring and program duration (short - few days to weeks; intermediate - few weeks to few months; long - a year or more). • Monitoring mode (real-time - instantaneous, continuous historical - integrated). • QA/QC requirements (data validation, equipment calibration, equipment and documentation, data handling, chain-of-custody, audits).
Source Characteristics Constraints	• Large number of air toxics compounds with high level of air emissions (volatile; semi-volatile, base/neutral, pesticides, PCBs, inorganic). • Mixed physical state (gas, particulates). • Non-homogeneous source. • Incomplete source characterization and data gaps.
Receptor Constraints	• Large number of receptors are identified for the specific application. • Large number of obstructions close to the receptors identified (trees, bushes, structures, etc.). • Accessibility to receptors. • Availability of utilities. • Security.
Environmental Constraints	• Complex Topography • Large water body(ies)
Data Quality Objective Constraints	• Limited or no applicable monitoring and analysis methodologies.
Resource Constraints	• Limited budget • Limited Time.

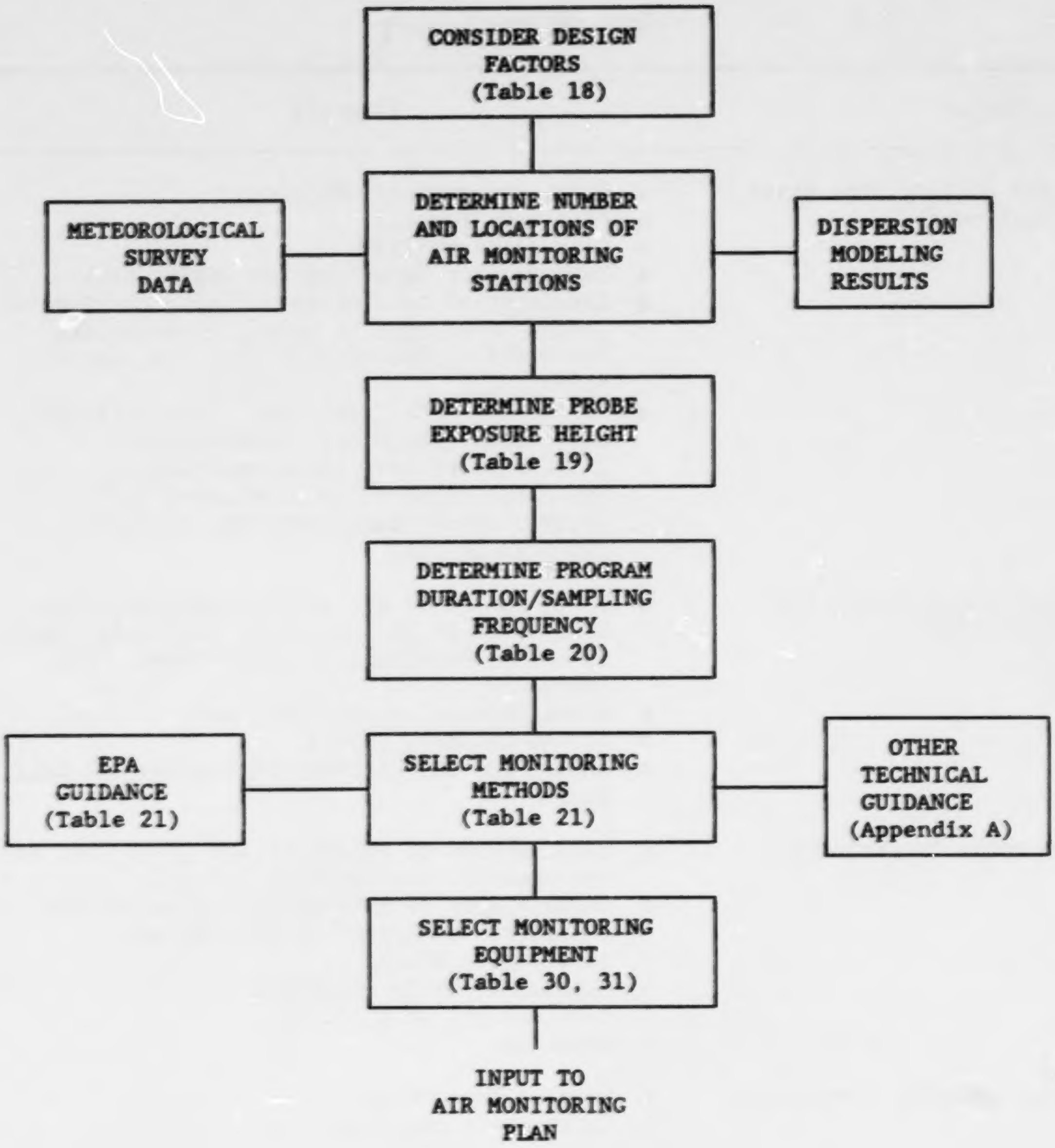
CONSIDER DESIGN FACTORS (Table 18)
METEOROLOGICAL SURVEY DATA
DETERMINE NUMBER AND LOCATIONS OF AIR MONITORING STATIONS
DISPERSION MODELING RESULTS
DETERMINE PROBE EXPOSURE HEIGHT (Table 19)
DETERMINE PROGRAM DURATION/SAMPLING FREQUENCY (Table 20)
EPA GUIDANCE (Table 21)
SELECT MONITORING METHODS (Table 21)
OTHER TECHNICAL GUIDANCE (Appendix A)
SELECT MONITORING EQUIPMENT (Table 30, 31)
INPUT TO AIR MONITORING PLAN

Figure 14. Design Air Monitoring Network.

Determine Number and Locations of Monitoring Stations

The number and location of monitoring stations for an air monitoring network depend on the site-specific characteristics listed below:

- Results of air dispersion modeling for the site area utilizing an atmospheric dispersion model applicable to the source and site (see Section 2.0 in this volume);
- Environmental characteristics (meteorology, topography, soil characteristics, etc.);
- Receptor characteristics (population centers, sensitive population and environmental locations, locations of calculated high concentrations of air toxics);
- Source characteristics (type and extent of contamination, locations of hot spots, etc.);
- Siting constraints; and
- Duration of the monitoring program.

Meteorological variables affecting monitoring network design include wind direction, wind speed, and atmospheric stability. These parameters can be used to define prevailing wind patterns and characterize local dispersion conditions.

Air monitoring programs that last for only 2 weeks or less (e.g., screening APAs) require some judgment about the placement of monitoring stations and their numbers. This is because the use of historical meteorological data would generally not provide accurate information on the meteorological conditions for the few days of sampling and analysis. However, the results of a meteorological survey onsite (see Section 3.4.2) conducted just prior to screening can help to identify expected wind patterns and downwind sampling sectors, and to characterize temporal wind direction variability. Meteorological forecast information can also be used to deploy screening air sampling equipment. Therefore, it is recommended that air screening samples be taken with portable sampling equipment.

Many factors should be considered in selecting locations and the number of monitoring stations for air monitoring programs with the duration of several weeks to several months, as discussed in the following paragraphs.

1. Predominant wind directions, based on historical records, for the monitoring period under consideration. This may involve the review of daily, weekly, and monthly meteorological records.

2. Time of the year the monitoring program is scheduled, to account, to the extent possible, for seasonal effects that could cause either high or low ambient air concentrations. Seasons that in general do not exhibit high-ground-level concentrations of the constituents involved should not be considered as candidate periods for air monitoring.

3. Use of a dispersion model (screening or refined) to calculate ground-level concentrations in the site vicinity and to determine locations of maximum calculated concentrations for short-term (up to 24 hours) averages and long-term (monthly, seasonal, and annual) averages. Input into the dispersion model, including source data, meteorology, topography, population centers, sensitive population, and environmental setting locations, should be defined for the time averages under consideration in order to obtain model output showing the receptors of maximum impact on the population and the environment. It is extremely important to consider concentration gradients revealed by plotting model results as isolpeths of concentration. Steep gradients suggest that a greater number of monitoring locations would be required than for broad gradients. In general, the impacts of elevated point sources display steep

concentration gradients and the impacts of low-level, area sources display broad concetration gradients.

4. Source size and configuration. It is preferable to locate an air monitoring station downwind from a source so that it will be exposed to a large fetch of the source area for a long period, considering the frequency of occurrence of wind direction.

5. Locations of sensitive receptors at the site perimeter and offsite. The locations and number of monitoring stations at sensitive receptors should be evaluated considering meteorological conditions conducive to high, ground-level concentrations of airborne air toxic constituents and their frequency of occurrence. From a practical viewpoint, it is important to consider the following:

   5A. Locations of anticipated high-ambient-ground-level concentrations of air toxic constituents and the frequency of occurrence of the meteorological conditions that are conducive to these levels. Depending on the monitoring objective, the first priority should be to select locations that will most frequently be exposed to high concentrations of such constituents.

   5B. Population and environmentally sensitive locations. In evaluating locations, it is important to consider the objectives of the monitoring program: to provide information on possible high impact at sensitive receptors, specifically, a high dose to an individual person or species or a high integrated dose to the nearby population. This factor will dictate the selection of a monitoring station representing small but highly sensitive or large but less sensitive population and environmental species.

6. Meteorological conditions

   6A. Wind directions and speeds and atmospheric stabilities conducive to high-ground-level concentrations of air toxic constituents for both short- and long-term averaging periods.

   6B. Local day/night wind flow and stability conditions for the area and monitoring period under consideration.

   6C. Characteristics of the regional flow regime for the area and the monitoring period under consideration. For example, it may occur that the regional flow for this site for the monitoring period of interest is generally southwesterly, and that the local night drainage flow under stable conditions is northeasterly. Accordingly, a monitoring location southwest of the site would be the upwind location for the regional flow and the downwind location for the more limiting local flow.

   6D. Results of previous air quality monitoring programs in the vicinity of the site that could be considered applicable to the case in question.

   6E. Results of previous air dispersion calculations for similar sources with meteorological data considered representative of the site conditions.

7. Topographical features that would influence the advection and transport of air toxic constituents. Examples include land surface elevations, valley channels, and the land-water interface.

Air monitoring station numbers and locations are highly site-specific, and therefore no specific recommendations are being made. Generally, however, a single downwind stationary monitor is not adequate to monitor for maximum concentrations. The examples presented in Section 4, as well as, the factors listed above, should be examined before deciding on a network design.

Determine Probe Exposure Height

The placement of air monitoring and meteorological stations must conform to a consistent set of criteria and guidance to ensure data comparability and compatibility. A detailed set of probe siting criteria for ambient air monitoring and meteorological programs is given in the following EPA document:

- U.S. EPA, May 1987. Ambient Monitoring Guidelines for Prevention of Significant Deterioration (PSD). EPA-450/4-87/007, Office of Air Quality Planning and Standards. Research Triangle Park, NC 27711.

A summary of key factors that should be considered as a part of the placement of an air quality monitoring station is given below. The reader is referred for more details to the above-referenced document.

Key siting factors include:

- Vertical placement above ground;
- Horizontal spacing from obstructions and obstacles;
- Unrestricted air flow; and
- Spacing from roads.

A summary of the key criteria associated with these siting factors for air monitoring stations is included in Table 19. The information included in that table should be used to the extent possible as a part of the monitoring network design to ensure that the monitoring program provides representative and unbiased data. However, site-specific constraints could make it very difficult to meet all criteria. For example, the occurrence of wooded areas around a Superfund site would make the perimeter siting very difficult, hence consideration should be given to the placement of stations onsite and offsite to the extent possible. Therefore, the use of the information in Table 19, coupled with a balanced evaluation by an experienced air quality and meteorology specialist is highly recommended.

Air emissions for most of the applications involved with Superfund sites are from ground level or near-ground-level releases. For a site area with no major obstructions and obstacles, the air sampler intake should be about 2-3 meters aboveground. For a site with nearby roadways, however, intake placement should take into account the effects of road dust reentrainment and vehicular emissions. In fact, a linear relationship should be established between the horizontal distance of the sampler intake from the roadway and the aboveground elevation of that intake. For any roadway accommodating more than 3000 vehicles per day, the intake should be between 5 and 25 meters from the edge of the nearest traffic lane. It should also be 15 meters aboveground for a distance of 5 meters from the nearest traffic lane and 2 meters aboveground for a distance of 25 meters from the nearest lane. For a roadway supporting less than 3000 vehicles per day, the intake should be placed at a distance greater than 5 meters from the edge of the nearest traffic lane and at a height of 2-15 meters aboveground.

TABLE 19. A SUMMARY OF KEY PROBE SITING CRITERIA FOR AIR MONITORING STATIONS

Factor	Criteria
Vertical spacing above ground	• Representative of the breathing zone and avoiding effects of obstruction, obstacles, and roadway traffic. Height of probe intake above ground i in general, 2-3 m above ground and 2-15 m above ground in the case of nearby roadways. • About 1 m or more above the structure where the sampler is located.
Horizontal spacing from obstruction and obstacles	• Minimum horizontal separation from obstructions such as trees is >20 m form the dripline and 10 m from the dripline when the trees act as an obstruction. • Distance from sampler inlet to an obstacle such as a building must be at least twice the height the obstacle protrudes above the sampler. • If a sampler is located on a roof or other structures, there must be a minimum of 2m separation from walls, parapets, penthouses, etc. • There must be sufficient separation between the sampler and a furnace or incinerator flue. The separation distance depends on the height and the nature of the emissions involved.
Unrestricted airflow	• Unrestricted airflow must exist in an arc of at least 270 degrees around the sampler, and the predominant wind direction for the monitoring period must be included in the 270 degree arc.
Spacing from roads	• A sufficient separation must exist between the sampler and nearby roadways to avoid the effect of dust re-entrainment and vehicular emissions on the measured air concentrations. • Sampler should be placed at a distance of 5-25 m from the edge of the nearest traffic lane on the roadway depending on the vertical placement of the sampler inlet which could be 2-15 m above ground.

Determine Program Duration and Sampling Frequency

The recommendations for program duration and frequency of monitoring are summarized in Table 20. Actual monitoring duration and frequency, however, will depend on the specific project objectives and resources. It is recommended that a representative number of air samples be collected during each step of the project to ensure a reasonable data base. The number of representative samples depends on many factors, and a simple statistical analysis may not provide a good basis for this number. The recommendations specified in Table 20 are based on the following factors:

- Augmentation of integrated sampling with continuous monitoring for steps that require more detailed data to enhance the data base;
- The resource requirements for laboratory analysis for organic and inorganic compounds; and
- Quality assurance/quality control requirements such as collocated field and trip blank samples and spike samples.

Samples taken over a very short period (a minute or so) are not representative of average air concentrations of air toxic constituents because of the high variability that could occur over short periods of time. For screening monitoring, therefore, it is recommended that the samples taken be averaged over at least 15 minutes and preferably over a longer period.

The information presented in Table 20 provides general guidance and should be tailored to the specific application.

Select Monitoring Methods and Equipment

The selection of air monitoring methods and equipment should be based on the consideration of a number of factors, including the following:

TABLE 20. PROGRAM DURATION AND FREQUENCY OF MONITORING AS A FUNCTION OF THE SUPERFUND PROJECT STEP

		Frequency	
Superfund Step	Monitoring Program Duration	Sampling Duration	Number of Samples
RI/FS - Screening APA • Screening Monitoring	• 1-2 days	• 15-30 minutes at each sampling location.	• 20-30 readings using THC analyzers. • 10-20 samples using colorimetric gas detection tubes or equivalent.
• Refined screening monitoring	same as above	• 24-hour integrated.	• 5-10 samples for organics in gas phase. • Limited QA/QC samples.
RI/FS - Refined APA • Refined Monitoring	• 4-6 weeks	• 24-hour integrated.	• 10 at each monitoring location for organics in gas phase, semi-volatile organics and in-orgnaics in particulate phase. • 10 at the collocated monitoring location for the same constituents as above. • Field and trip blanks, spiked, spilt and surrogate samples on a case-by-case basis.

(Continued)

TABLE 20. (Continued)

Superfund Step	Monitoring Program Duration	Frequency	
		Sampling Duration	Number of Samples
Remedial Design • Refined Monitoring	• 3-12 months depending on the length of the pilot treatability study.	• 24-hour integrated	• 10-30 at each monitoring location for organics in gas phase, semi-volatile organics and inorganics in particulate phase. • 10-30 at the collocated monitoring location for the same constituents as above. • Field and trip blanks, spiked, split, and surrogate samples, on a case-by-case basis.
• Refined Screening Monitoring	same as above	• 24-hour continuous	• Continuous at each of the designated monitoring locations for organics only.

(Continued)

TABLE 20. (Continued)

Superfund Step	Monitoring Program Duration	Frequency	
		Sampling Duration	Number of Samples
Remedial Action			
- Refined Monitoring	- Several months to more than a year, depending on the length of the site clean-up.	- 24-hour integrated	- One sample every day[a] at each sampling location for organics in gas phase, semi-volatile organics and inorganics in particulate phase. - Same frequency as above for the collocated monitoring and for the same constituents as above. - Field and trip blanks, spikes, split and surrogate samples, on a case-by-case basis.
- Refined screening monitoring	Same as above	- 24-hour continuous	- Continuous at each of the designated monitoring locations for organics only.
- Screening Monitoring	Same as above	- 24-hour continuous	- Continuous at each of the designated monitoring locations for inorganics and total hydrocarbons.

(Continued)

TABLE 20. (Continued)

		Frequency	
Superfund Step	Monitoring Program Duration	Sampling Duration	Number of Samples
Operation and Maintenance			
• Refined Monitoring	• Phase I - one year	• 24-hour integrated	• One sample every 12th day at each sampling location for organics in gas phase, semi-volatile organics, and inorganics in particulate phase. • Same frequency as above for the collocated monitoring & for the same constituents as above. • Field and trip blanks, spiked, split and surrogate samples, on a case-by-case basis.
• Refined Monitoring	• Phase II - two to five years	• 24-hour integrated	• Twleve samples per year for the same constituents as above. • Same frequency as above for the collocated monitoring and for the same constituents as above. • Field and trip blanks on a case-by-case basis.

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[a] Frequency should be adjusted based on results of first 1 to 2 weeks of sampling.

- Physical and chemical properties of compounds;
- Relative and absolute concentrations of compounds;
- Relative importance of various compounds in program objective;
- Method performance characteristics;
- Potential interferences present at site;
- Time resolution requirements; and
- Cost restraints.

Various classes of contaminants must usually be monitored by different methods, depending on the compounds and their physical/chemical properties. Another condition that affects the choice of monitoring technique is whether the compound is primarily in the gaseous phase or is found adsorbed to solid particles or aerosols.

Screening for the presence of air constituents involves techniques and equipment that are rapid, are portable, and can provide real-time monitoring data. Air contamination screening will generally be used to confirm the presence of a release or to establish the extent of contamination during the screening phase of the investigation. Quantification of individual compounds is not as important during screening as during initial and additional air monitoring; however, the technique must have sufficient specificity to differentiate hazardous constituents of concern from potential interferences, even when the latter are present in higher concentrations. Detection limits are ususally much higher for screening devices than for quantitative methods.

Laboratory analytical techniques are used to provide positive identification of the components and the accurate and precise measurement of concentrations. This generally means that the preconcentration and/or storage of air samples will be required. Therefore, methods chosen for refined monitoring usually involve a longer analytical time period, more sophisticated equipment, and more rigorous QA procedures. Turnaround time for data is a key factor to evaluate when considering offsite analyses.

The following list of references provides guidance on air monitoring methodologies:

- U.S. EPA. June 1983. Technical Assistance Document for Sampling and Analysis of Toxic Organic Compounds in Ambient Air. EPA-600/4-83-027. NTIS PB 83-239020. Office of Research and Development. Research Triangle Park, NC 27711.
- U.S. EPA. April 1984. Compendium of Methods for the Determination of Toxic Organic Compounds in Ambient Air. EPA-600/4-84-041. Office of Research and Development. Research Triangle Park, NC 27711.
- U.S. EPA. September 1986. Compendium of Methods for the Determination of Toxic Organic Compounds in Ambient Air. EPA/600/4-87-006. NTIS PB87-168696. Office of Research and Development. Research Triangle Park, NC 27711.
- U.S. EPA. June 1987. Compendium Method TO-12: Method for Determination of Non-Methane Organic Compounds (NMOC) in Ambient Air Using Cryogenic Preconcentration and Direct Flame Ionization Detection (PDFID). Research Triangle Park, NC 27711.
- U.S. EPA. May 1988. Compendium Method TO-14: The Determination of Volatile Organic Compounds (VOCs) in Ambient Air Using SUMMA$_T$ Passivated Canister Sampling and Gas Chromatographic Analysis. Quality Assurance Division. Research Triangle Park, NC 27711.
- NIOSH. February 1984. NIOSH Manual of Analytical Methods. NTIS PB 85-179018. National Institute for Occupational Safety and Health. Cincinnati, OH 45226.

- U.S. EPA. September 1983. *Characterization of Hazardous Waste Sites - A Methods Manual: Volume II, Available Sampling Methods.* EPA-600/4-83-040. NTIS PB 84-126929. Office of Solid Waste. Washington, DC 20460.

- U.S. EPA. September 1983. *Characterization of Hazardous Waste Sites - A Methods Manual: Volume III, Available Laboratory Analytical Methods.* EPA-600/4-83-040. NTIS PB 84-126929. Office of Solid Waste. Washington, DC 20460.

- U.S. EPA. 1986. *Test Methods for Evaluating Solid Waste. 3rd Edition.* EPA SW-846. GPO No. 955-001-00000-1. Office of Solid Waste. Washington, DC 20460.

- ASTM. 1982. *Toxic Materials in the Atmosphere.* ASTM, STP 786. Philadelphia, PA 19103.

- ASTM. 1980. *Sampling and Analysis of Toxic Organics in the Atmosphere.* ASTM, STP 721. Philadelphia, PA 19103.

- ASTM. 1974. *Instrumentation for Monitoring Air Quality.* ASTM, SP 555. Philadelphia, PA 19103.

- APHA. 1977. *Methods of Air Sampling and Analysis.* American Public Health Association. Washington, DC 20005.

- ACGIH. 1983. *Air Sampling Instruments for Evaluation of Atmospheric Contaminants.* American Conference of Governmental Industrial Hygienists. Cincinnati, OH 45211.

Recommended air monitoring methods are given in Table 21. These recommendations are based on typical Superfund site conditions and are a function of APA sophistication level and Superfund activity. Therefore, alternative methods should be carefully considered and selected on a case-by-case basis. A summary of screening methods and their applicability to various compound classes is presented in Table 22. A listing of refined air monitoring methods is included in Table 23. Additional summaries of these refined methods and associated equipment are presented in Tables 24 through 30. A brief overview of emerging technologies (e.g., mobile mass spectrometry and laser/infrared spectrometry) is presented in Table 31. Until these technologies are further developed, however, it is recommended that standard air monitoring methods be selected for Superfund APA applications.

A bibliography of air monitoring methods for sampling and analysis is presented in Appendix A. A list of commercially available equipment for screening and refined screening monitoring is presented in Tables 32 and 33. Refined monitoring systems generally require the purchase of many individual components. Therefore, a convenient summary of the numerous vendor alternatives is not practical for this document.

3.4.5 Document Air Monitoring Plan

The site/source-specific air monitoring plan should be documented to facilitate the implementation of the selected monitoring strategy. A recommended procedure for this phase is presented in Figure 15.

Required Documentation: Quality Assurance Project Plan

The EPA requires any project involving environmental measurement, such as the air monitoring for toxic substances of Superfund sites, to prepare a Quality Assurance Project Plan (QAPP). The QAPP, which is distinct from any general project plan, describes the organization of the project and the assignment of responsibility for those specific QA/QC activities required to meet the projet DQOs. A detailed description of the QAPP is given in the following document:

TABLE 21. SUMMARY OF AIR MONITORING METHOD RECOMMENDATIONS

Activity	Monitoring Recommendations	Objectives
RI/FS	• Screening - THC analyzers - Colorimetric gas detection tubes	• Determine whether or not toxic air releases exist at the site and its perimeter using gross measurement techniques. • Obtain qualitative information of on-site and off-site air toxic concentration for defining a more refined monitoring.
	• Refined Screening - Portable field GC Analyzer	• Support refined monitoring and provide near realOtime data for site monitoring.
	• Refined - whole air samplers with GC/MS analysis for indicator compounds and for an expended list (samples split) of compounds (TO-14). - whole air samplers for volatile organics (TO-14). - impingers if necessary (TO-5, TO-6, TO-8). - PUF sampling as necessary (TO-9). - Hi-Vol (PM-10) for particulate matter as necessary (40 CFR 50, Part J.	• Determine refined levels of air toxic concentrations on-site and at the site perimeter. • Utilize these data to define air monitoring plan for the next Superfund step (if necessary). • Assist in air quality data interpretation. • Determine refined levels of toxic air contaminants on-site, at the site perimter, and off-site. • Utilize results of the air monitoring in risk assessment for the no-action alternative and evaluating remedial alternatives. • Provide sufficient information for the design and implementation of remedial action steps.

(Continued)

TABLE 21. (Continued)

Activity	Monitoring Recommendations	Objectives
Remedial Design	● Refined - Whole air samplers for volatile organic (TO-14). - impingers if necessary (TO-5, TO-6, TO-8). - PUF sampling as necessary for semi-volatile organics (TO-9). - Hi-Vols (PM-10) for particulate matter as necessary (40 CFR 50, Part J).	● Determine the effects of pilot treatability study and ambient air quality and make use of the data in the design of the implementation of remedial action step.
	● Refined Screening - Portable field GC analyzer.	● Support refined monitoring and provide near-realtime data for site monitoring.
Remedial Action	● Refined - Whole air samplers for volatile organic (TO-14). - impingers if necessary (TO-5, TO-6, TO-8). - PUF sampling as necessary for semi-volatile organics (TO-9). - Hi-Vols (PM-10) for particulate matter as necessary (40 CFR 50, Part J).	● Provide data in support of protecting public health and the environment as well as on-site workers under routine and non-routine releases.

(Continued)

TABLE 21. (Continued)

Activity	Monitoring Recommendations	Objectives
Remedial Action (Continued)	• Refined screening - portable field GC analyzer.	• Provide near-realtime data in support of protecting public health and the environment as well as on-site workers under routine and non-routine releases.
	• Screening - Electrochemical alarm cells.	• Provide near-realtime data in support of protecting on-site workers and sufficient information for protecting public health and the environment in case of non-routine release.
Operation and Maintenance	• Refined - whole air samplers for volatile organics (TO-14). - impingers as necessary (TO-5, TO-6, TO-8). - PUF samplers as necessary for semi-volatile organics (TO-9). - Hi-Vol (PM-10) for particulate matter as necessary (40 CFR 50, Part J).	• Assess the long-term effect of the remedial action on public health and environment.

TABLE 22. SUMMARY OF SCREENING TECHNIQUES FOR DETECTION OF ORGANIC AND INORGANIC COMPOUNDS IN AMBIENT AIR

	Applicable Methods (Reference Table 3)										
	Total Hydrocarbon Analyzers		Colorimetric Methods			Electrochemical Detectors and Alarms	Portable GC Analyzers				Portable Pumps & Filters
Compound Class (Ref. Table 9)	Fid[1]	Infrared	Gas Detection Tubes	Continuous Flow Colorimeter	Tape Monitor		GC/FID	PID & GC/PID	GC/ECD	GC/FPD	
A. Volatile Organics											
1. Aliphatics	x	x									
2. Aromatics	x	x	x[2]				x	xx[3]			
3. Halogenated Species	x		x						xx[4]		
4. Oxygenated species	x	x	x				x				
5. Sulfur-containing species	x		x					x		x	
6. Nitrogen-containing species	x	x	x							xx	
B. Volatile Inorganics											
1. Acid gases			x		x	x[HCH]					x[5]
2. Sulfur-Containing species[6]			x			x				x	
C. Semi-Volatile Organics											
1. Phenols	x		x				x		x		
2. Esters	x	x					x				x
3. Chlorinated benzenes			x					x[7]	xx		
4. Amines	x		x				x		x	x	
5. Pesticides Ethers	x	x					xx				
6. Alkadienes	x							x	x		
7. Miscellaneous alphatics and aromatics	x						x				
8. Polynuclear aromatic hydrocarbons	x	x					x				x
9. Pesticides	x								x		x
10. Polychlorinated byphenyls (PCBs)	x								x		

(Continued)

TABLE 22. (Continued)

	Applicable Methods (Reference Table 3)										
	Total Hydrocarbon Analyzers		Colorimetric Methods			Electrochemical Detectors and Alarms	Portable GC Analyzers				Portable Pumps & Filters
Compound Class (Ref. Table 9)	Fid[1]	Infrared	Gas Detection Tubes	Continuous Flow Colorimeter	Tape Monitor		GC/FID	PID & GC/PID	GC/ECD	GC/FPD	
D. Non-Volatiles											
1. Inorganics metals and nonmetals			x			x^{Hg}					x

Abbreviations:
FID = Flame ionization detector
PID = Photoionization detector
FPD = Flame photometric detector
GC = Gas chromatograph
ECD= Electron capture detector

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[1] FID alone will not distinguish between categories of compounds. An "x" in this column means that the category is measured along with all other categories.

[2] Colorimetric gas detection tubes may not be applicable to every compound in a given category. COnsult manufacturer's information for specific applicability.

[3] Where more than one GC or total hydrocarbon detector method is listed, "xx" indicates a preferred method.

[4] As an option for halogenated species, the ECD may be used in conjunction with a Hall detector or PID for more accurate identification of compounds.

[5] Pump/filter methods are applicable to particulate species in the indicated categories.

[6] Mercaptans may be detected using FID or infrared methods.

[7] For chlorobenzenes, if a PID is used, it should be used in conjunction with an ECD.

TABLE 23. A SUMMARY OF REFINED SAMPLING AND ANALYSIS TECHNIQUES FOR ORGANICS AND INORGANICS IN AIR

Technique	Method No.	Type of Compounds
I. Organic Compounds:		
Traps		
• Sorption onto Tenax GC packed cartridges using low volume pump and GC/MS analysis.	TO-1	• Volatile, nonpolar organic (e.g., aromatic hydrocarbons, chlorinated hydrocarbons) having boiling points in the range of 80° to 200°C, in gas or vapor phase.
• Sorption onto carbon molecular sieve packed cartridge using low volume pump and GC/MS analyses	TO-2	• Highly volatile, nonpolar organics (e.g., vinyl chloride, vinylidene chloride, benzene, toluene) having boiling points in the range of -15° to +120°C, in gas or vapor phase.
• Cryogenic trapping of analytes in the field and GC/FID or ECD analyses.	TO-3	• Volatile, nonpolar organics having boiling points in the range of -10° to +200°C, in gas or vapor phase.
• Sorption onto polyurethane (PUF) using low volume or high volume pump and GC/ECD analysis.	TO-4	• Organochlorine pesticides and PCBs, in particulate phase.
• Sorption onto Thermosorb/N packed cartridges using low volume pump GC/MS analysis.	TO-7	• N-Nitrosodimethylamine in gas phase.
• Sorption onto PUF using low volume or high volume pump and high resolution Gas Chromatography/High Resolution Mass Spectrometry (HRGC/HRMS).	TO-9	• Dioxin

(Continued)

TABLE 23. (Continued)

Technique	Method No.	Type of Compounds
Whole Air Samplers		
• Whole air samples are collected in a SUMMA® passivated stainless steel canister and high resolution GC coupled with mass specified spectrometer (GC MS-SIM or GC-MS-Scan).	TO-14	• Volatile, nonpolar organic (e.g., aromatic hydrocarbons) chlorinated hydrocarbons having boiling points of -30°C to about 215°C.
• Whole air samples extracted directly from ambient air and analyzed using cryogenic preconcentration and direct flame ionization detector (PDFID), or air samples are collected in a canister and analyzed by PDFID.	TO-12	• Non-methane organic compounds (NMOC).
• Whole air samples are collected in Tedlar® bags and subject to GC/FID or ECD analysis or high resolution GC compiled with MS-SIM or MS-SCAN.	Modified TO-3 or TO-14	• TO-14 or TO-3 compounds.
• Liquid Impingers	--	---
• Dinitrophenylhydrazine Liquid Impinger sampling using a low volume pump and High Performance Liquid Chromatography/UV analysis.	TO-5	• Aldehydes and ketones
• Aniline liquid impinger sampling using a low volume pump and HPLC analysis.	TO-6	• Phosgene
• Sodium Hydroxide Liquid impinger sampling using a low volume pump and HPLC analysis.	TO-8	• Cresol/phenol

(Continued)

TABLE 23. (Continued)

Technique	Method No.	Type of Compounds
II. Inorganic Compounds:		
Filter Samplers		
• High-volume sampler and Atomic Absorption (AA) or Inductive Coupled Plasma (ICP).	40 CFR Part 50.7 Appendix B.	• Metals in particulate phase.
• PM-10 high volume sampler and AA or ICP	40 CFR part 50. Appendix J (for sampling Methodology only).	• Inhalable metals in particulate phase (up to 10 microns in diameter).
• High-volume sampler	40 CFR Part 50.11	Total suspended particulate (TSP)
• PM-10 high-volume sampler	40 CFR Part 50. Appendix J	• Inhalable particulate up to 10 microns in diameter.

TABLE 24. SUMMARY OF SAMPLING AND ANALYTICAL METHODS FOR REFINED MONITORING FOR ORGANIC AND INORGANIC COMPOUNDS IN AMBIENT AIR VOLATILE AROMATICS[1]

Sampling and Analysis Approach	Method Designation	Detection Limit	Accuracy[2]	Precision[3]	Advantages	Disadvantages
CRYOGENIC PRECONCENTRATION/GC/FID/EC - Vapor phase organics are condensed in a cryogenic trap. Carrier gas transfers the condensed sample to a GC column. Adosrbed compounds are eluted from the GC column and measured by FID or EC detectors.	TO-3	0.1 ppbv (100 ml sample)	90-110%	±15%	• Collects wide variety of volatile organic compounds. • Standard procedures are available. • Contaminants common to adsorbent materials are avoided. • Low blanks	• Moisture levels in air can cause freezing problems. • Difficult to use in field. • Expensive.
CARBON MOLECULAR SIEVE ADSORPTION AND G/MS OR GC/FID - Selected volatile organic compounds are captured on carbon molecular sieve adsorbents. Compounds are thermally desorbed and analyzed by GC/MS techniques.	TO-2	1-200 pptv (20 ml sample)	70-95% (biased low)	±10-40%	• Trace levels of volatile organic compounds are collected and concentrated on sorbent material. • Atmospheric moisture not collected.	• Some trace levels of organic species are difficult to recover from the sorbent.
TENAX GC ADSORPTION AND GC/MS OR GC/FID - Ambient air is drawn through organic polymer sorbent where certain compounds are trapped. The cartridge is transferred to the laboratory for analysis. Using GC/MS or GC/FID.	TO-1	.01-1 ppbv (20 ml sample)	80-100%	±20%	• Good volume of air can be sampled. • Water vapor is not collected. • Wide variety of compounds collected. • Standard procedures available.	• Highly volatile compounds and certain polar compounds are not collected. • Rigorous clean-up required. • No possibility of multiple analysis. • Low breakthrough volumes for some compounds.

(Continued)

TABLE 24. (Continued)

Sampling and Analysis Apprdach	Method Designation	Detection Limit	Accuracy[2]	Precision[3]	Advantages	Disadvantages
SUMMA® PASSIVATED CANISTER AND GC/FID/ECD or GC/MS - Whole air samples are collected in an evacuated stainless steel canister. VOCs are concentrated in the laboratory with cryogen trap. VOCs are revolatilized, separated on a GC column, and passed to one or more detectors for identification and quantitation.	TO-14	0.5-4 ppb	90-100%	±10%	• Best method for broad speciation of unknown trace volatile organics. • Simple sampling approach.	• Sample components may be adsorbed or decompose through interaction with container walls. • Condensation may be a problem at high concentrations (ppm). • Copmlex equipment preparation required.

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[1] See Table 3-6 for listing of analytes.

[2] Accuracy - The agreement of an analytical measurement with a true or accepted value. Values int his table are expressed as Percent Recovery (%R = Measured Value/True Value x 100).

[3] Precision - The reproducibility of repeated measurement of the same property usually made under prescribed conditions. Values in this table are expressed as Relative Percent Difference (RPD = Range/Mean x 100).

TABLE 25. SUMMARY OF SAMPLING AND ANALYTICAL METHODS FOR REFINED MONITORING FOR ORGANIC AND INORGANIC COMPOUNDS IN AMBIENT AIR VOLATILE HALOGENATED HYDROCARBONS[1]

Sampling and Analysis Approach	Method Designation	Detection Limit	Accuracy[2]	Precision[3]	Advantages	Disadvantages
TENAX GC ADSORPTION AND GC/MS OR GC/ECD - Ambient air is drawn through a cartridge containing Tenax where certain volatile organic compounds are adsorbed. Compounds are transferred by programmed thermal desorption into a GC and detected by MS or ECD.	TO-1	.01-1 ppb	80-100%	±20%	• Moisture is not collected • Large sample volume can be concentrated. • Documented standard procedures available with extensive QA/QC database • Practical for field use • Low detection limits	• Contamination problems possible. • Artifact formation problems. • Rigorous clean-up required. • No possibility of multiple analyses • Low breakthrough volumes for some compounds.
CARBON MOLECULAR SIEVE ADSORPTION AND GC/MS OR GC/ECD - Ambient air is drawn through a cartridge containing carbon molecular sieve where highly volatile compounds are adsorbed. Compounds are thermally desorbed to a GC where they are quantitatively measured using MS or EC detectors.	TO-2	1-200 pptv (20 ml sample)	70-95%	±10-40%	• Efficient collection of polar compounds. • Wide range of application • Highly volatile compounds are adsorbed • Easy to use in field.	• Water collected and can de-activate adsorption sites. • Thermal desorption of compounds may be difficult.
CRYOGENIC TRAPPING AND GC/ECD - Vapor phase organics are condensed in a cryogenic trap. Carrier gas transfers the condensed sample to a GC column. Adsorbed compounds are eluted from the GC column and determined by MS or EC detectors.	TO-3	0.1 pptv (100 ml sample)	90-110%	±10%	• Large database • Excellent long-term storage • Wide applicability • Allows multiple analyses • Best method for broad speciation of unknown VOCs • Easy sample collection • Consistent recoveries	• Moisture condensation • Integrated sampling is difficult

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[1] See Table 3-6 for listing of analytes.

[2] Accuracy - The agreement of an analytical measurement with a true or accepted value. Values in this table are expressed as Percent Recovery (%R = Measured Value/True Value x 100).

[3] Precision - The reproducibility of repeated measurement of the same property usually made under prescribed conditions. Values in this table are expressed as Relative Percent Difference (RPD = Range/Mean x 100).

TABLE 26. SUMMARY OF SAMPLING AND ANALYTICAL METHODS FOR REFINED MONITORING FOR ORGANIC AND INORGANIC COMPOUNDS IN AMBIENT AIR VOLATILE OXYGENATES[1]

Sampling and Analysis Approach	Method Designation	Detection Limit	Accuracy[2]	Precision[3]	Advantages	Disadvantages
SUMMA PASSIVATED CANISTER AND GC/FID/EC OR GC/PID/EC OR GC/MS - Whole air samples are collected in an evacuated stainless steel canister. VOCs are concentrated in the laboratory with cryogen trap. VOCs are revolatized, separated on a GC column and passed to one or more detectors for identification and quantification.	TO-14	0.5-20 ppb	90-110%	±10%	• Low cost • High sensitivity • Positive compound ID	• Calibration time consuming • Compound identification is not absolute • Low sensitivity • Expensive
	TO-3	0.5-20 ppb	90-110%	±20%		
Air sample is drawn through dinitrophenylhydrazine impinger solution using a low volume pump. The solution is analyzed using HPLC with a UV detector.	TO-5	1-5 ppbv	80-120%	±10%	• Specific for aldehydes and ketones • Good stability for derivative compounds formed • Low detection limits	• Sensitivity limited by reagent priority. • Potential for evaporation of liquid over long term.
Air stream is drawn through a Tenax cartridge and adsorbed to it. Desorption from Tenax is by thermal desorption to GC/MS or GC/FID.	TO-1	1-5 ppbv	75-125%	±15-20%	• Collect and concentrate large volume sample with trace concentration. • Moisture is not a problem. • Broad use-reference methods • Low detection limit • Easy to use in field	• Blank contaminants may be a problem • Single analysis per sample • Artifact formations with time

(Continued)

TABLE 26. (Continued)

Sampling and Analysis Approach	Method Designation	Detection Limit	Accuracy[2]	Precision[3]	Advantages	Disadvantages
Collection of whole air samples in SUMMA® passivated stainless steel canisters. VOCs are separated by GC methods and measured by MS or multi-detector techniques	TO-14	1 ppbv			• Must calibrate separate detectors • Compound identification not positive. Lengthy data interpretation. Does not differentiate targeted compounds from interfering compounds.	• Equipment expensive • Operator skill level important.

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[1] See Table 3-6 for listing of analytes.

[2] Accuracy - The agreement of an analytical measurement with a true or accepted value. Values int his table are expressed as Percent Recovery (%R = Measured Value/True Value x 100).

[3] Precision - The reproducibility of repeated measurement of the same property usually made under prescribed conditions. Values in this table are expressed as Relative Percent Difference (RPD = Range/Mean x 100).

TABLE 27. SUMMARY OF SAMPLING AND ANALYTICAL METHODS FOR REFINED MONITORING FOR ORGANIC AND INORGANIC COMPOUNDS IN AMBIENT AIR SEMI-VOLATILE PHENOLICS[1]

Sampling and Analysis Approach	Method Designation	Detection Limit	Accuracy[2]	Precision[3]	Advantages	Disadvantages
SODIUM HYDROXIDE LIQUID IMPINGER AND HPLC/UV - Ambient air is drawn through two midget impingers. Phenols are trapped as phenolates in NaOH solution and analyzed by HPLC.	TO-8	1 ppb	75-125%	±20%	• 4,6-dinitro-2-methylphenol (50/1600) specific to class of compounds. • Good stability. • Detect non-volatile as well as volatile compounds.	• Subject to interferences • Limited sensitivity
ADSORPTION OF TENAX AND GC/FID OR GC/MS - Ambient air is drawn through organic polymer sorbent where certain organic compounds are trapped. The cartridge is transferred to the laboratory for analysis. Compounds are desorbed by heating.	TO-1	1-200 ppt	70-95%	±10-40%	• Good QA/QC database • Wide range of application • Easy to use in field.	• Desorption of some compounds difficult • Blank contamination possible • Artifact formation on adsorbent • High humidy reduces collection efficiency
HIGH VOLUME PUF/TENAX SAMPLER AND GC/ECD - Sorption onto PUF.	TO-4	0.2-2 ng/m^3	60-100%	±20%	• Wide range of application • Easy to use - low blanks • Excellent collection and retention efficiencies	• Possibility of contamination.

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[1] See Table 3-6 for listing of analytes.

[2] Accuracy - The agreement of an analytical measurement with a true or accepted value. Values int his table are expressed as Percent Recovery (%R = Measured Value/True Value x 100).

[3] Precision - The reproducibility of repeated measurement of the same property usually made under prescribed conditions. Values in this table are expressed as Relative Percent Difference (RPD = Range/Mean x 100).

TABLE 28. SUMMARY OF SAMPLING AND ANALYTICAL METHODS FOR REFINED MONITORING FOR ORGANIC AND INORGANIC COMPOUNDS IN AMBIENT AIR SEMI-VOLATILE BASE/NEUTRAL EXTRACTS[1]

Sampling and Analysis Approach	Method Designation	Detection Limit	Accuracy[2]	Precision[3]	Advantages	Disadvantages
HIGH VOL GFF AND PUF FILTERS AND GC/FID/ECD OR GC/MS - Particulates filtered in field and solvent extracted in lab. Analyzed by GC/MS.	TO-4	0.2-200 ng/m^3	28-85%	±15%	• Effective for broad range of compounds • Easy to preclean and extract • Low blanks	• Possible contamination • Loss of volatile organics during storage
HIGH VOL. XAD-2 RESIN - Particulates filtered from ambient air with low or hi vol filter. Filters solvent extracted and analses completed using GC/MS.	TO-4 (modification)	0.2-200 ng/m^3	80-120%	±15%	• Effective for broad range of compounds. • Easy to clean • Broad database • Good retention of compounds	

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[1] See Table 3-6 for listing of analytes.

[2] Accuracy - The agreement of an analytical measurement with a true or accepted value. Values int his table are expressed as Percent Recovery (%R = Measured Value/True Value x 100).

[3] Precision - The reproducibility of repeated measurement of the same property usually made under prescribed conditions. Values in this table are expressed as Relative Percent Difference (RPD = Range/Mean x 100).

TABLE 29. SUMMARY OF SAMPLING AND ANALYTICAL METHODS FOR REFINED MONITORING FOR ORGANIC AND INORGANIC COMPOUNDS IN AMBIENT AIR SEMI-VOLATILE PESTICIDES/PCBs[1]

Sampling and Analysis Approach	Method Designation	Detection Limit	Accuracy[2]	Precision[3]	Advantages	Disadvantages
HIGH VOL GLASS FIBER AND PUF FILTERS AND GC/ECD -Particulates collected on filters. Compounds solvent extracted and analyzed using GC/ECD.	TO-4	0.2-200 ng/m^3	28 to 85-100%	±15%	• Broad range of application • Low blanks • Easy to use • Reusable • High sensitivity	• Can lose volatile compounds in storage • Possibility of contamination
HIGH VOL GLASS FIBER FILTER AND XAD-2 RESIN TO FILTER AND ADSORB PARTICULATES	TO-4 (modification)	0.2-200 ng/m^3	80-120%	±20%	• Can analyze broad range of compounds (more efficient than PUF).	

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[1] See Table 3-6 for listing of analytes.

[2] Accuracy - The agreement of an analytical measurement with a true or accepted value. Values int his table are expressed as Percent Recovery (%R = Measured Value/True Value x 100).

[3] Precision - The reproducibility of repeated measurement of the same property usually made under prescribed conditions. Values in this table are expressed as Relative Percent Difference (RPD = Range/Mean x 100).

TABLE 30. SUMMARY OF SAMPLING AND ANALYTICAL METHODS FOR REFINED MONITORING FOR ORGANIC AND INORGANIC COMPOUNDS IN AMBIENT AIR VOLATILE IN-ORGANICS[1]

Sampling and Analysis Approach	Method Designation	Detection Limit	Accuracy[2]	Precision[3]	Advantages	Disadvantages
HIGH VOL GFF AND AA/ICP - Particulates are removed from air stream with a GFF or PUF filter, dissolved and analyzed by spectrometric methods.	TO-4	1-5 ng/m^3	±25%	±10%	• Wide range of applications • Standard methods • Low detection limits	
VAPOR PHASE METALS (Sb, As, Pb, Ni, Se, Ag, Hg) IMPINGER AND AA/GFA - Collection of vapor phase metals on sorbents and in impinger solutions.		1-5 ng/m^3			• Standard methods • High sensitivity • QA/QC database available • Spedific method for each metal	• Possible breakthrough • High blanks • Interferences
VAPOR PHASE CN - MCEF and Sodium Hydroxide Liquid Impinger	TO-8/ ISP/EP A 335.1 or .3	1-5 ng/m^3			• Standard methods for each metal	• Potential interferences

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[1] See Table 3-6 for listing of analytes.

[2] Accuracy - The agreement of an analytical measurement with a true or accepted value. Values int his table are expressed as Percent Recovery (%R = Measured Value/True Value x 100).

[3] Precision - The reproducibility of repeated measurement of the same property usually made under prescribed conditions. Values in this table are expressed as Relative Percent Difference (RPD = Range/Mean x 100).

TABLE 31. SUMMARY OF SAMPLING AND ANALYTICAL METHODS FOR REFINED MONITORING FOR ORGANIC AND INORGANIC COMPOUNDS IN AMBIENT AIR DEVELOPING TECHNOLOGIES[1]

Sampling and Analysis Approach	Method Designation	Detection Limit	Accuracy[2]	Precision[3]	Advantages	Disadvantages
MOBILE MASS SPECTROMETER (MS/MS, MS/MS/MS) OR (GC/MS)	None	1 ppb			• Compound identification in complex mixtures. • Direct sampling • Field operation	• Expensive • Skilled operators • Low sensitivity
LONG PATH OPTICAL ABSORPTION - Bi-static open air transmission of broadband radiation is used to obtain spectra of trace gases in ambient air. Specialized systems are available for both the infrared and ultraviolet spectral regions. Laser-based systems also are available for more restricted applications.	None	2 ppb			• Direct Field measurements • Minimum time requirement • No sampling required • Line-of-sight coverage.	

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[1] See Table 3-6 for listing of analytes.

[2] Accuracy - The agreement of an analytical measurement with a true or accepted value. Values int his table are expressed as Percent Recovery (%R = Measured Value/True Value x 100).

[3] Precision - The reproducibility of repeated measurement of the same property usually made under prescribed conditions. Values in this table are expressed as Relative Percent Difference (RPD = Range/Mean x 100).

TABLE 32. TYPICAL COMMERCIALLY AVAILABLE SCREENING MONITORING AND ANALYSIS EQUIPMENT FOR ORGANICS AND INORGANICS IN AIR*

Technique	Manufacturers	Compounds Detected	Approximate Detection Limit	Comments
1. THC Analyzers				
FID (Total Hydrocarbon Analyzer)	Beckman MSA, Inc. Thermo Electron, Inc.	Most organics	0.5 ppmv	Does not repond uniformly to most organic compounds on carbon basis.
Infrared Analysis	Foxboro/Wilkes	Most organics	1-10 ppmv	Some inorganic gases (H_2O, CO) will be detected and tehrefore are potential interferences.
2. Colorimetric Gas Detection Tubes and Monitors				
Gas Detection Tubes	Draeger, Matheson, Kitagawa	Varous organics and inorganics	0.1 to 1 ppmv	Highly subject to interference, sensitivity and selectivity highly dependent on compound of interest.
Continuous Flow Colorimeter	CEA Instruments, Inc.	Acrylonitrile, formaldehyde, phosgene, and various organics	0.05 to 0.5 ppmv	Sensitivity and selectivity similar to detector tubes.

(Continued)

TABLE 32. (Continued)

Technique	Manufacturers	Compounds Detected	Approximate Detection Limit	Comments
Colorimetric Tape Monitor	KHDA Scientific	Toluene, di-isocyanate, dinitro toluene, phosgene, and various inorganics	0.05-0.5 ppmv	Same as above.
3. Electrochemical alarm cells	Foxboro, MSA, CEA Instruments, Sensidyne	Wide range of inorganics, also combustion gases	ppmv	Quantitative information for a single compound by each cell. Requires an array of cells.
4. Portable GC** Analyzers				
GC/FID (portable)	Foxboro/Century, Thermo Electron, Inc.	Most organics except that polar compounds may not elute from the column.	0.5 ppbv	Qualitative as well as quantitative information obtained, does not respond uniformly to organic compounds.

(Continued)

TABLE 32. (Continued)

Technique	Manufacturers	Compounds Detected	Approximate Detection Limit	Comments
PID and GC/PID (portable)	HNU, Inc. Photovac, Inc. Thermo Environmental Instruments, Inc.	Most organic compounds can be detected with the exception of methane	0.1 to 100 ppbv	Selectivity can be adjusted by selection of lamp energy. Aromatics most readily detected.
GC/ECD (portable)	Thermo Electron, Inc.	Halogenated and nitro-substituted compounds.	0.1 to 100 ppbv	Response varies widely from compound to compound.
GC/FPD (portable)	Thermo Electron, Inc.	Sulfur or phosphorus-containing compounds	10-100 ppbv	Both inorganic and organic sulfur or phosphorus compounds will be detected.
5. Portable pumps and filters	Gilian Instrument Corporation, SKC, Inc., Millipore, Inc.	Inorganics particulates and semi-volatile particulates	100 ppbv-1 ppmv	Special sorbent plugs have to be used to collect semi-volatiles.

* based on Riggins, 1983.

**Classified as a refined screening technique.

GC = Gas Chromatograph
PID = Photoionization Detector
FPD = Flame Photometric Detector
FID = Flame Ionization Detector
ECD = Electron Capture Detector

TABLE 33. SUMMARY OF REFINED SCREENING MONITORING EQUIPMENT FOR ORGANIC COMPOUNDS IN AMBIENT AIR

Sampling and Analysis Approach	Manufacturer	Detection Limit	Precision	Mode of Operation	Advantages and Disadvantages
Scentograph PC operated portable GC analyzer utilizing Argon ionization/electron capture detector (ECD) with optional photo-ionization detector, preconcentrator and a heated column with temperature adjustable to 140°C. Up to 16 different compounds can be processed at any time. Library is up to 100 compounds. On-going calibration is by injecting standard calibration gas.	Sentex Sensing Technology	Low ppb range when operated as ambient air monitor.	About 5-10% high reproducibility.	Realtime intermittent. Automatic sampling at 5-15 minute intervals depending on operating parameters.	Advantages: • Near real time continuous concentrations of air toxic constituents. • Good accuracy and low detection limit for a field technique. • Eliminates in-accuracies associated with the handling of samples obtained by integrator samplers that have to be shipped for laboratory analysis. • Has an option for more than one detector. Disadvantages: • Can analyze only a limited number of air toxic constituents at a time. • Subject to inaccuracies introduced by field conditions and field operators.

(Continued)

TABLE 33. (Continued)

Sampling and Analysis Approach	Manufacturer	Detection Limit	Precision	Mode of Operation	Advantages and Disadvantages
Photovac Model 10S70 portable GC analyzer utilizing photoionization detector (PID) with a range of 5 different energy lamps to provide selectivity for different chemical groups, isothermal oven control for the multi capilarry column. Up to 25 compounds can be processed at any time. Includes 4 libraries of 25 compounds each. Calibration is by injecting standard calibration gas.	Photovac, Inc.	0.1 to several ppb for substituted benzenes and haloethylenes. 1 ppm for saturated haloalkanes.	About 5-10% high reproducibility.	Realtime intermittent. Automatic sampling is 5-15 minute intervals depending on operating parameters.	Advantages: • Similar to the ones mentioned above with the exception that it uses only one detector. Disadvantages: • Similar to the ones mentioned above with the addition of: --Isothermal oven control is up to 50°C. This GC cannot operate at higher temperatures. This reduces the range of volatile organics that can be analyzed. Useful mainly for high volatile organics. --Cannot use detectors other than the PID.
HNU Model 3010P or 311 portable GC analyzer. The 301PD model can utilize either a PID or FID and the 311 model can utilize a PID only. Includes isothermal temperature control of up to 300°C for the 301PD model and up to about 200°C for the 311 model. Calibrate with either the compounds of interest or with a reference compound. Up to 20 compounds can be processed at any time.	HNU Systems, Inc.	0.1 to several ppb depending on the number of compounds involved and the mix.	Not readily available but expected to be in the same range as above.	real time continuous	Advantages: • Similar to the ones above for the 301PD model. • Similar to the ones above for the 311 model with the exception that it uses only one detector. Disadvantages: • Similar to ones listed for the Scentograph GC. With the addition of: • No temperature adjustments. • No library for retention times.

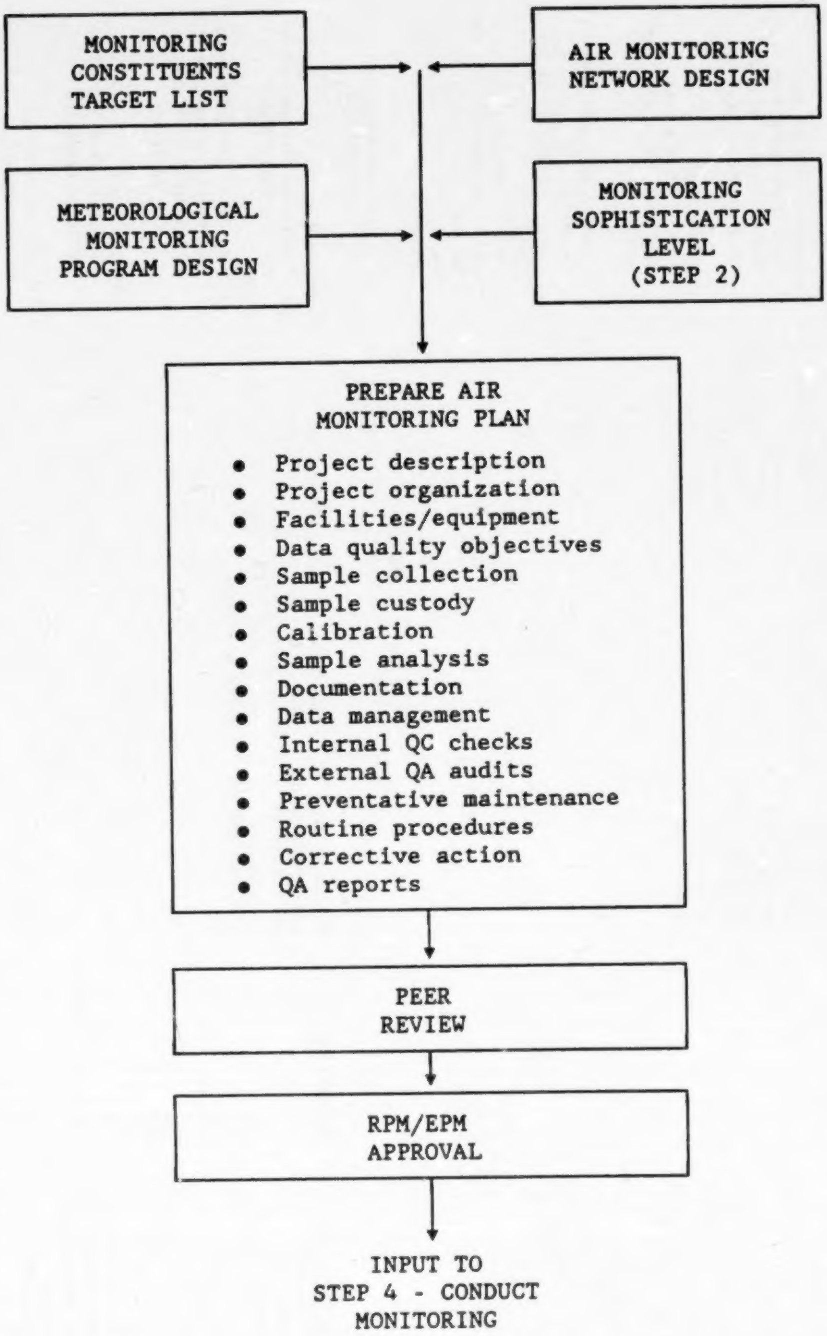

MONITORING CONSTITUENTS TARGET LIST
AIR MONITORING NETWORK DESIGN
METEOROLOGICAL MONITORING PROGRAM DESIGN
MONITORING SOPHISTICATION LEVEL (STEP 2)
PREPARE AIR MONITORING PLAN
• Project description
• Project organization
• Facilities/equipment
• Data quality objectives
• Sample collection
• Sample custody
• Calibration
• Sample analysis
• Documentation
• Data management
• Internal QC checks
• External QA audits
• Preventative maintenance
• Routine procedures
• Corrective action
• QA reports
PEER REVIEW
RPM/EPM APPROVAL
INPUT TO STEP 4 - CONDUCT MONITORING

Figure 15. Document Air Monitoring Plan.

- U.S. EPA, 1983. Interim Guidelines and Specifications for Preparing of Quality Assurance Project Plans. QAMS-005/80 (EPA-600/4-83-004; NTIS PB83-170514)

Additional guidance is available in the following:

- U.S. EPA. 1984. Guide to the Preparation of Quality Assurance Project Plans. Office of Toxic Substances, Office of Pesticides and Toxic Substances. Washington, DC 20460.

- U.S. EPA. 1977. Quality Assurance Handbook for Air Pollution Measurement Systems, Volumes I and II. EPA-600/9-76-005. Office of Research and Development. Research Triangle Park, NC 27711.
- ASTM. 1988. Annual Book of Standards: Part 26, Gaseous Fuels; Coal and Coke; Atmospheric Analysis. American Society for Testing and Materials, Philadelphia, PA 19103.

- U.S. EPA. 1987. Ambient Monitoring Guidelines for Prevention of Significant Deterioration (PSD). EPA-450/4-87-007. Research Triangle Park, NC 27711.

- U.S. EPA. 1987. Onsite Meteorological Program Guidance for Regulatory Modeling Applications. EPA-450/4-87-013. Research Triangle Park, NC 27711.

Recommended EPA documents that provide detailed information on the calibration process necessary for air monitoring QAPPs are:

- U.S. EPA, 1987. Quality Assurance Handbook for Air Pollution Measurement Systems, Volumes I and II. EPA-60019-76-005. Office of Research and Development. Research Triangle Park, NC 27711.

- U.S. EPA, 1987. Ambient Monitoring Guidelines for Prevention of Significant Deterioration (PSD). EPA-450/4-87-007. Office of Air Quality Planning and Standards. Research Triangle Park, NC 27711.

- U.S. EPA, 1987. Onsite Meteorological Program Guidance for Regulatory Modeling Applications. EPA-450/4-87-013. Office of Air Quality Planning and Standards. Research Triangle Park, NC 27711.

Content of Quality Assurance Project Plan

The following is a breakdown and description of the contents of a typical QAPP.

Project Description. A general description of the project, including the experimental design, must be provided. The description must be complete enough to enable responsible parties to review and approve the proposed plan. The plan shall include the following items:

- Statement of objectives;
- Description of the air toxics monitoring program;
- Outline of the sampling method and frequency of sampling;
- Outline of the method of data analysis to be used;
- Anticipated duration of the project; and
- Intended use of the acquired data.

Project Organization and Responsibility. A list of all personnel assigned to data collection, measurement, and verification, including brief functional descriptions of their responsibilities, must be prepared. An organization chart and description of the qualifications of all project personnel is also recommended.

Facilities, Services, Equipment, and Supplies. The utilization of the resources required for the project must be considered. Questions such as the following should be addressed:

- Can the plan be completed meeting all monitoring requirements in a safe manner?
- Are the equipment and supplies needed to complete the project adequate and available in sufficient quantities?
- Who maintains and calibrates the equipment required to make the measurements?
- How frequently is the equipment calibrated and serviced?
- What standards are used to calibrate the equipment?
- Are special facilities needed to service or dispose of supplies?

DQOs for Measurement Data. It is important to define the acceptance limits for data generated for the project to ensure that it is complete and representative of the site. An attempt should be made to discuss the acceptance limits and control factors for sampling and analysis errors. This includes means for determining if the data generated meet the requirements of the monitoring objectives.

Sample Collection. EPA protocols for sample collection procedures should be referenced and the procedures and equipment to be used in the project should be described. In addition, a description of equipment and supplies used to collect and transport samples and of preservatives used and holding-time limitations should be provided. Record-keeping procedures must be included to document pertinent detail.

Sample Custody. Procedures for field sampling operations as well as laboratory operations are to be provided. It is critical to ensure that records are adequate to support legal documentation of the collection, preservation, transport, and transfer of samples for laboratory analysis.

Calibration Procedures. The calibration procedure for each measurement parameter should be described, either through reference to the standard method used or through an ad hoc written description. The frequency of calibration and the frequency with which continuing calibration is verified also should be described. The standards for the calibration and the acceptable sources should be documented. Calibration should address, when applicable, instrument flow rate, electronic zero and span for analytical instruments and meteorological equipment, calibration gas requirements, and external zero and span for analytical instruments.

Laboratory Analysis Procedures. EPA-approved procedures for the monitoring parameters should be discussed. Similarly, a written description of the analytical procedures and SOPs that will be used in the monitoring program should be addressed.

Data Management. Data management includes the procedures established to store and maintain both field and laboratory data collection and analysis records.

Recordkeeping/Documentation. The QAPP should specify requirements for field and laboratory documents. For example, the use of logbooks, forms, and other records of monitoring/analytical operations should be identified.

Internal QC Checks. The internal QC methods for the air quality monitoring project should be described. Items to be addressed include:

- Replicates;
- Spiked samples;
- Split samples;
- Control charts;

- Blanks;
- Internal standards;
- Zero and span gases;
- Quality control samples;
- Surrogate samples;
- Calibration standards and devices; and
- Reagent checks.

External QA Audits. Audits should be scheduled to verify that components of the monitoring program are in place and operating as described for both field and laboratory QC procedures.

Preventive Maintenance. Preventive maintenance, including frequency and methods of implementation, should be addressed in the QA plan. A list of the spare parts needed to ensure prompt equipment repair and thus to minimize downtime should also be prepared.

Procedures to Assess Data Quality. Specific procedures to assess the precision and accuracy of measurement data should be discussed in the QAPP. This includes standard statistical methods of evaluating data quality. On completion of testing, the data can be reviewed by an independent reviewer to assess the quality of the reported values.

Feedback and Corrective Action. The criteria for acceptable data should be described, as should the corrective action to be taken if the data quality is not acceptable. The personnel responsible for reviewing the data and for implementing correction action should also be identified.

Quality Assurance Reports to Management. QAPPs should provide a mechanism for the regular review of data quality. These periodic reports include data quality measurements, performance and system audits, and a listing of measures taken to resolve problems noted. Each of these elements should be included in the final project report.

Review and Approval of Quality Assurance Project Plan

A draft of the QAPP should be reviewed by the EPA Project Officer and the QA Officer to ensure that the plan contains the procedures necessary to document the prevision, accuracy, and completeness of the data generated.

The draft should also be subjected to a peer review--preferably review by another air expert who was not a primary author of the plan. At the discretion of the RPM/EPM, this review could be conducted within the same organization that developed the plan.

Authority for final approval of the plan rests with the RPM/EPM, and project cost and schedule are major considerations.

3.5 STEP 4 - CONDUCT MONITORING

3.5.1 Overview

Field and analytical operations of the air monitoring program should be conducted commensurate with the monitoring plan developed during Step 3. However, successful implementation of the monitoring plan requires adequate field staff and attention to QA/QC factors. Therefore, the operational approach illustrated in Figure 16 should be applied to Superfund air monitoring programs.

3.5.2 Field Staff Qualifications and Training

The air monitoring program should be designed and directed by staff with air toxics monitoring experience. For many applications the site health and safety officer will be qualified to direct the field monitoring operations. However, it should be recognized that site health and safety officers, as well as staff with similar backgrounds (e.g., industrial hygienists), may not have experience in air toxics monitoring at the low detection levels (parts per billion or micrograms per cubic meter) specified in ARARs to protect offsite receptors. It is recommended, therefore, that

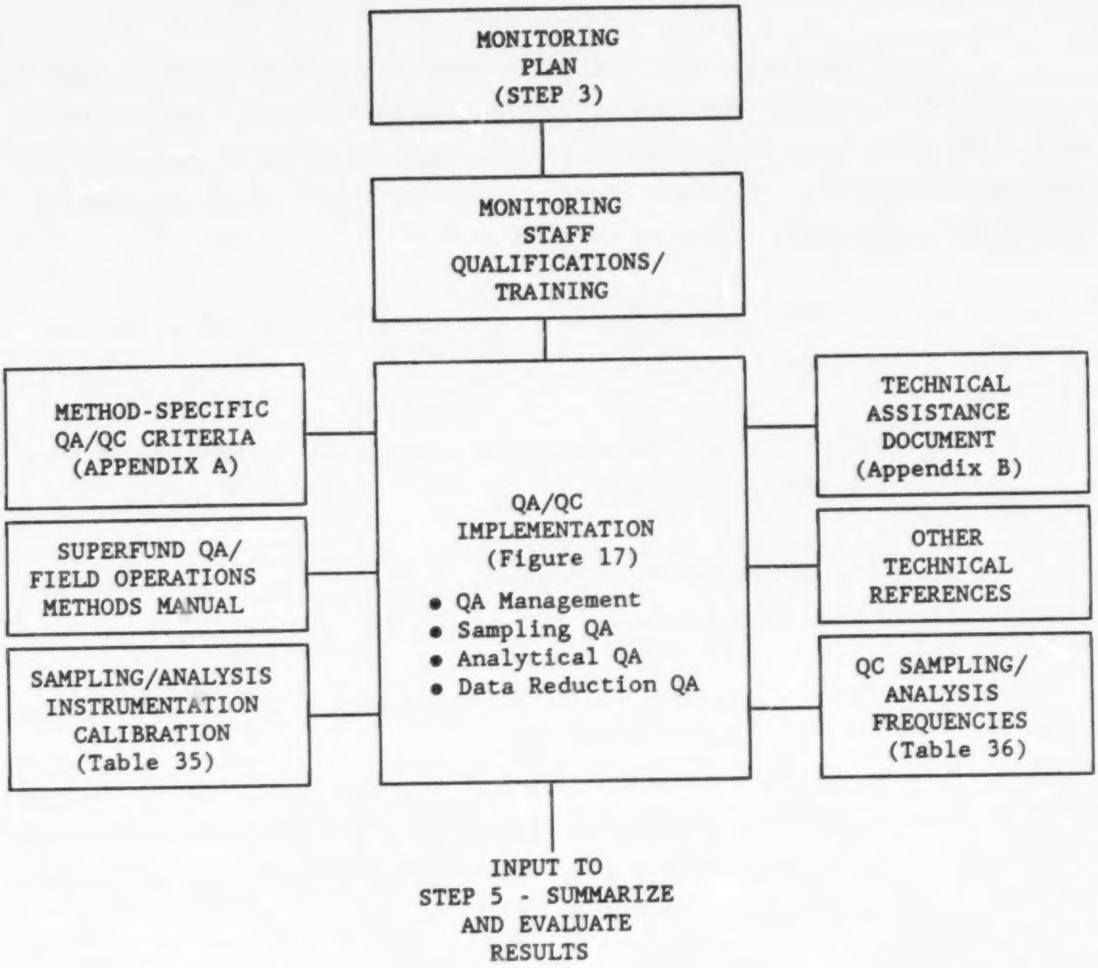

MONITORING PLAN (STEP 3)
MONITORING STAFF QUALIFICATIONS/ TRAINING
METHOD-SPECIFIC QA/QC CRITERIA (APPENDIX A)
SUPERFUND QA/ FIELD OPERATIONS METHODS MANUAL
SAMPLING/ANALYSIS INSTRUMENTATION CALIBRATION (Table 35)
QA/QC IMPLEMENTATION (Figure 17)
• QA Management
• Sampling QA
• Analytical QA
• Data Reduction QA
TECHNICAL ASSISTANCE DOCUMENT (Appendix B)
OTHER TECHNICAL REFERENCES
QC SAMPLING/ ANALYSIS FREQUENCIES (Table 36)
INPUT TO STEP 5 - SUMMARIZE AND EVALUATE RESULTS

Figure 16. Step 4 - Conduct Monitoring.

Superfund air monitoring projects be designed and implemented by air quality specialists with relevant ambient air toxics monitoring experience.

It is imperative that the field staff who will be involved with the operation of the network be trained personnel with sufficient understanding of, and hands-on experience with, air toxics monitoring instrumentation and laboratory analysis. The field operators must be sensitive to the overall aspects of the program including the need for:

- In-depth understanding of the operating principles for the equipment involved.
- Consistent performance of the preventive maintenance actions recommended by the manufacturer.
- Consistent performance of the routine tests of the equipment used to ensure it operates properly.
- Timely implementation of equipment checks and calibrations.
- Maintenance of network logbook and monitoring station logbooks to document pertinent field activities. These activities must be documented in a clear manner to enable the use of the logs as needed in the future.
- Careful handling of samples collected to avoid the contamination or loss of materials collected, and the documentation in detail of every sample sent for laboratory analysis to maintain the correct chain-of-custody.
- Maintenance of the program sampling and analysis schedule.
- Checks of regenerated equipment (traps, plugs, canisters, etc.) that are returned by the laboratory.

- Consistent collection of QA/QC samples, including collocated blanks.

- Communication with the site RPM/EPM to ensure that he is kept apprised of any problem area and the means of mitigating it.

- Communication with the air toxics specialist assigned to the project to expedite the exchange of information that is essential to smooth network operation.

An integral part of the network operation is the close communication with the designated contact at the offsite laboratory to ensure that:

- The samples shipped are received on time.

- Analysis is performed on time.

- Any technical issues that develop are handled promptly to minimize loss of data.

- Laboratory results are received in time for an evaluation of the performance of the monitoring program and a preliminary assessment of, the implications of the results to the Superfund project.

It is clear from this discussion that well-trained field personnel are the key to a good air toxics monitoring program.

3.5.3 Quality Assurance/Quality Control

Quality assurance/quality control topics to be addressed in the QAPP, required for Superfund monitoring activities, have been identified in Section 3.4.5. During the conduct of the air monitoring program, rigorous conformance to the QAPP will be vital to meet project objectives. Major QA/QC elements that should be implemented during the operational phase of an air monitoring program (see Table 34) include procedures to assess and control the quality of the sampling, analytical, data reduction, and management procedures.

QA management involves implementing project-specific administrative procedures to control QA/QC functions. The potential for, and types of, quality problems vary for the sampling, analytical, and data reduction functions. Therefore, the QA/QC requirements must be developed individually for each of these functions. Comprehensive QA/QC recommendations applicable to Superfund and air monitoring programs are available. Key references include the following:

Superfund program-specific QA/QC recommendations

- U.S. EPA March 1986. Quality Assurance/Field Operations Methods Manual. Draft.

Generic air toxics monitoring QA/QC recommendations

- U.S. EPA. June 1983. Technical Assistance Document for Sampling and Analysis of Toxic Organic Compounds in Ambient Air. EPA-600/4-83-027. NTIS PB 83-239020. Office of Research and Development. Research Triangle Park, NC 27711.

Monitoring method-specific QA/QC recommendations

- U.S. EPA. April 1984. Compendium of Methods for the Determination of Toxic Organic Compounds in Ambient Air. EPA-600/4-84-041. Office of Research and Development. Research Triangle Park, NC 27711.

- U.S. EPA. September 1986. Compendium of Methods for the Determination of Toxic Organic Compounds in Ambient Air. EPA/600/4-87-006. NTIS PB87-168696. Office of Research and Development. Research Triangle Park, NC 27711.

TABLE 39. QUALITY ASSURANCE (QA) ACTIVITIES TO BE SPECIFIED IN PROGRAM PLAN

QA Management
- QA System Design
- Design Control
- Data Evaluation
- Audit Procedures
- Corrective Action
- QA Reports to Program Management
- Training

Sampling QA
- Instrument Calibration and Maintenance
- Collection of Routine Quality Control Samples
- Data Recording
- Sample Labeling, Preservation, Storage, and Transport
- Chain-of-Custody Procedures

Analytical QA
- Method Validation Requirements
- Instrument Calibration and Maintenance
- Quality Control Sample Analysis
- Data Recording

Data Reduction QA
- Merging Sampling and Analysis Data Files
- Storage of Raw and Intermediate Data
- Data Validation.

- U.S. EPA. June 1987. Compendium Method TO-12: Method for the Determination of Non-Methane Organic Compounds (NMOC) in Ambient Air Using Cryogenic Preconcentration and Direct Flame Inonzation Detection (PDFID). Research Triangle Park, NC 27711.

- U.S. EPA. May 1988. Compendium Method TO-14: The Determination of Volatile Organic Compounds (VOCs) in Ambient Air Using SUMMA® Passivated Canister Sampling and Gas Chromatographic Analysis. Quality Assurance Division. Research Triangle Park, NC 27711.

- NIOSH. February 1984. NIOSH Manual of Analytical Methods. NTIS PB 85-179018. National Institute of Occupational Safety and Health. Cincinnati, OH.

Meteorological monitoring QA/QC recommendations

- U.S. EPA. June 1987. On-Site Meteorological Program Guidance for Regulatory Modeling Applications. EPA-450/4-87-013. Office of Air Quality Planning and Standards. Research Triangle Park, NC 27711.

Air quality monitoring QA/QC recommendations

- U.S. EPA. February 1983. Quality Assurance Handbook for Air Pollution Measurements Systems: Volume IV, Meteorological Measurements. EPA-600/4-82-060. Office of Research and Development. Research Triangle Park, NC 27711.

- U.S. EPA. May 1987. Ambient Monitoring Guidelines for Prevention of Significant Deterioration (PSD). EPA-450/4-87/007. NTIS PB81-153231. Office of Air Quality Planning and Standards. Research Triangle Park, NC 27711.

These references should be consulted to specify project-specific QA/QC requirements based on the approach illustrated in Figure 17.

The technical QA recommendations presented in On-Site Meteorological Program Guidance for Regulatory Modeling Applications (U.S. EPA, June 1987) and Technical Assistance Document (TAD) for Sampling and Analysis of Toxic Organic Compounds in Ambient Air (U.S. EPA, June 1983) should also be implemented. The calibration requirements and QC sampling/analysis frequency criteria presented in Tables 35 and 36, respectively, are examples of the QA recommendations presented in the TAD.

The QA criteria presented in monitoring method-specific documents (e.g., Technical Assistance Document for Sampling and Analysis of Toxic Organic Compounds in Ambient Air, U.S. EPA, June 1983) should also be implemented if these QA recommendations are more stringent than those stipulated in the TAD.

Supplemented technical QA recommendations based on other available references (e.g., Quality Assurance Handbook for Air Pollution Measurement Systems, U.S. EPA, February 1983) should also be implemented as warranted for factors not addressed in the previous documents.

3.6 STEP 5 - SUMMARIZE AND EVALUATE RESULTS

3.6.1 Overview

Monitoring data available from Step 4 should be summarized and evaluated to provide input to site-specific risk assessments and the Superfund decision-making process. The recommended data processing approach is illustrated in Figure 18. This approach consists of the following major elements:

- Validate data;
- Summarize data; and
- Model dispersion to extrapolate monitoring data.

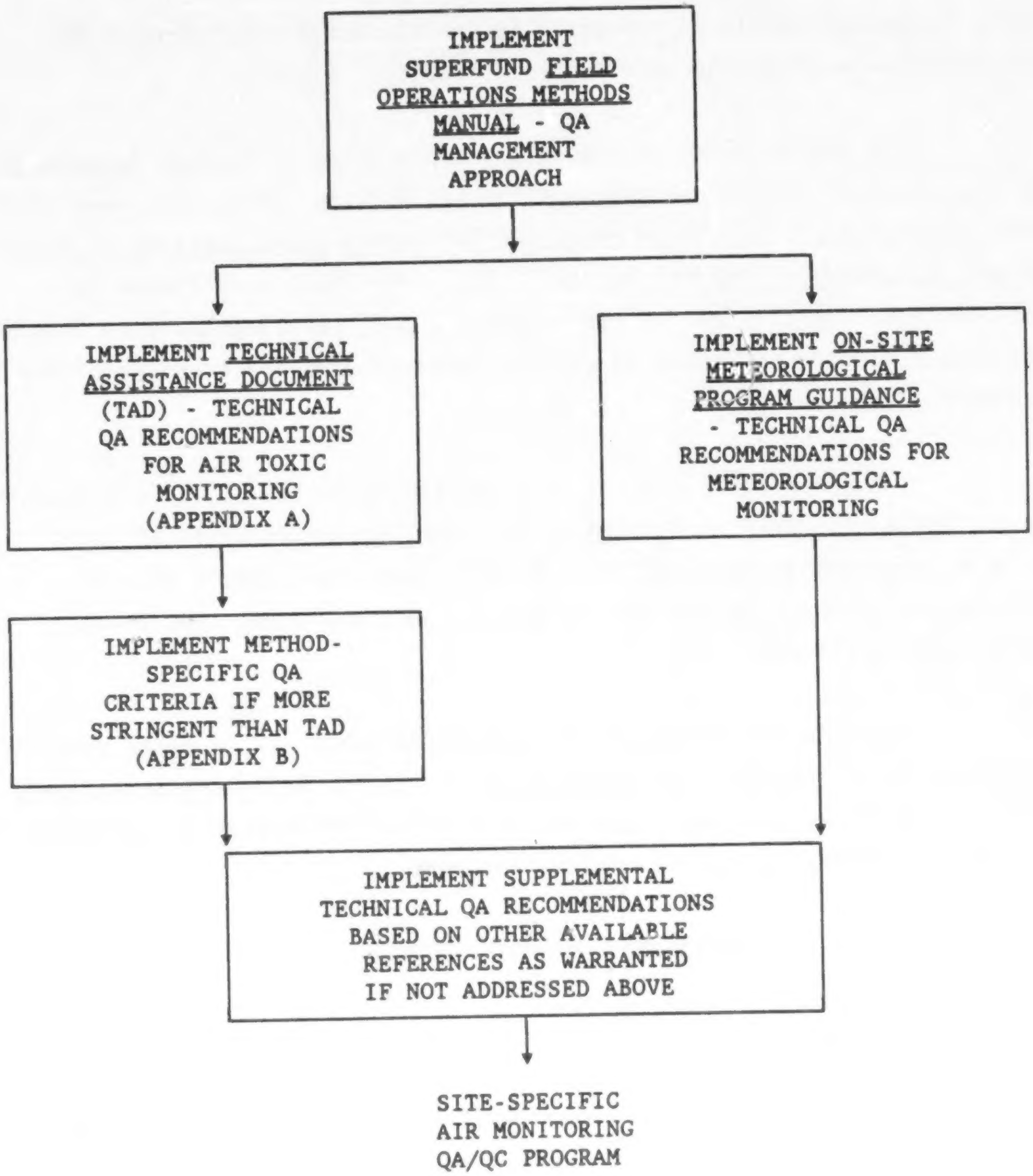

IMPLEMENT SUPERFUND FIELD OPERATIONS METHODS MANUAL - QA MANAGEMENT APPROACH
IMPLEMENT TECHNICAL ASSISTANCE DOCUMENT (TAD) - TECHNICAL QA RECOMMENDATIONS FOR AIR TOXIC MONITORING (APPENDIX A)
IMPLEMENT ON-SITE METEOROLOGICAL PROGRAM GUIDANCE - TECHNICAL QA RECOMMENDATIONS FOR METEOROLOGICAL MONITORING
IMPLEMENT METHOD-SPECIFIC QA CRITERIA IF MORE STRINGENT THAN TAD (APPENDIX B)
IMPLEMENT SUPPLEMENTAL TECHNICAL QA RECOMMENDATIONS BASED ON OTHER AVAILABLE REFERENCES AS WARRANTED IF NOT ADDRESSED ABOVE
SITE-SPECIFIC AIR MONITORING QA/QC PROGRAM

Figure 17. Superfund Air Monitoring QA/QC Strategy.

TABLE 35. CALIBRATION REQUIREMENTS FOR SAMPLING AND ANALYSIS INSTRUMENTATION

Device	Parameter Calibrated	Method of Calibration	Approximate Frequency	Comments
Sampling Instrumentation				
Sampling pump and controller	Flow rate	Wet or dry test meter or calibrated rotameter	Weekly	
Sample volume measurement device (usually a dry test meter)	Total volume	Wet test meter	Weekly	Must be determined at known atmospheric pressure and temperature. Flow rate should be similar to that used for sampling.
Analytical Instruments Continuous monitors (e.g., FID, PID, FPD, etc.)	Response	Generation of test atmosphere of known concentrations.	Daily or more frequently if required.	Test atmosphere should be referenced to a primary standard (e.g., NBS benzene in air). Flow/pressure conditions should duplicate sampling process.
Chromatographic istruments	Column performance and retention time for each analyte.	Injection of standard using the same process as for sample injection.	Daily or more frequently if required.	Standard composition should be checked against primary standards if available.
	Response for each analyte	Same as above	Same as above	Same as above.
GC/MS	Response and retention time for each analyte	Same as for other chromatographic instruments	Same as for other chromatographic instruments	Same as for other chromatorgaphic instruments.
GC/MS	Mass spectral resolution and turning parameters.	a) Introduction or perfluoro-compound directly into MS. b) Injection of tuning standard (e.g., bromofluorobenzene) into GC.	Daily	Selection of tuning standards will be dependent on type of analysis being performed.

TABLE 36. TYPICAL SAMPLING/ANALYSIS FREQUENCIES FOR QC SAMPLES

Type of Sample	Typical Frequency
Field Blanks	Each sample set; at least 10% of total number of samples.
Laboratory Blanks	Daily; at least 10% of total number of samples. Each batch of samples.
Spiked Samples	Each sample set; weekly.
Duplicate (parallel) Samples	10% of total number of samples; each sample set.
Instrument Calibration Standards	Daily.
Reference Samples	Weekly.
Series (backup) samples[a]	Each Sample set.

[a] Duplicates of each sample that are archived.

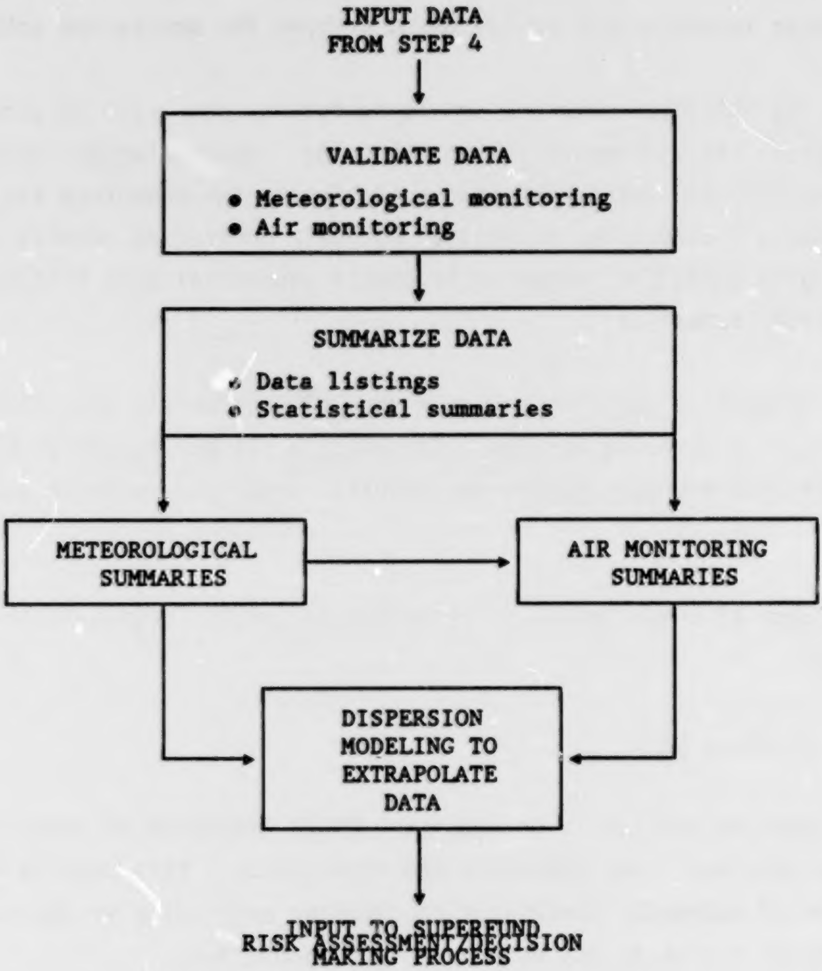

INPUT DATA FROM STEP 4
VALIDATE DATA
• Meteorological monitoring
• Air monitoring
SUMMARIZE DATA
• Data listings
• Statistical summaries
METEOROLOGICAL SUMMARIES
AIR MONITORING SUMMARIES
DISPERSION MODELING TO EXTRAPOLATE DATA
INPUT TO SUPERFUND RISK ASSESSMENT/DECISION MAKING PROCESS

Figure 18. Step 5 - Summarize and Evaluate Results.

Raw monitoring data should be checked for validity before they are used as a part of the data base for site decision-making. These validity checks are an integral part of the QA/QC program for monitoring activities.

The validated data set should be further processed to provide meteorological and air concentration summaries. Meteorological data are also used to classify the upwind/downwind (relative to the Superfund air emission source) exposure conditions associated with air monitoring results. The validated data should be processed to obtain sequential data listings as well as statistical summaries.

Dispersion modeling may be warranted for certain situations to supplement air monitoring results. For example, it may be useful to extrapolate site boundary monitoring results to offsite receptor locations of interest.

Each of these topics is discussed in greater detail in the following subsections.

3.6.2 Validate Data

Data validation is an important QA/QC component of Superfund monitoring programs. For Superfund APA applications, this usually involves a combination of automated checks during computer processing of the raw data as well as manual review of the data by an air specialist.

Meteorological Data Validation

Raw meteorological data should be checked for validity using equipment calibration, audit, and performance data. Comprehensive technical recommendations for meteorological data validation presented in the following reference should be adopted for Superfund APAs:

- U.S. EPA, June 1987. On-Site Meteorological Program Guidance for Regulatory Modeling Applications. EPA-450/4-87-013. Office of Air Quality Planning and Standards. Research Triangle Park, NC 27711.

Table 37 presents meteorological data screening criteria. It is an example of the technical data validation recommendations presented in the reference cited above.

Air Monitoring Data Validation

Air monitoring data should also be validated utilizing equipment calibration, audit, and performance data in a manner similar to that recommended for meteorological data.

Analytical results should be subject to a thorough validation process. This process requires the use of a qualified chemist who is familiar with the data validation requirements and process. Validation of analytical results for one sample could take from 15 minutes to more than an hour, depending on the type of analysis, the number of air toxic constituents involved, interference, contamination, and other factors.

Raw air quality data received from portable GC analyzers or other continuous instruments should also be checked for validity. The performance of the analyzer, calibration, and QA results should be considered.

Air monitoring data validation efforts should include evaluating collocated station results and audit results to determine data precision and accuracy, as follows:

TABLE 37. SUGGESTED METEOROLOGICAL DATA SCREENING CRITERIA[a] (U.S. EPA, JUNE 1987)

Meteorological Variable	Screening Criteria[a]
Wind Speed	Flag data if the value: • Is less than zero or greater than 25 m/s; • Does not vary by more than 0.1 m/s for 3 consecutive hours; and • Does not vary by more than 0.5 m/s for 12 consecutive hours.
Wind Direction	• Is less than zero or greater than 360 degrees; • Does not vary by more than one degree for more than three consecutive hours; and • Does not vary by more than ten degrees for 18 consecutive hours.
Temperature	• Is greater than the local record high; • Is less than the local record low; (The above limits could be applied on a monthly basis.) • Is greater than a 5° change from the previous hour; and • Does not vary by more than 0.5°C for 12 consecutive hours.
Temperature Difference	• Is greater than 0.1°C/m during the daytime; • Is less than -0.1°C/m during the nighttime; and • Is greater than 5.0°C/m or less than -3.0°C/m.
Dew Point Temperature	• Is greater than the ambient temperature for the given time period. • Is greater than a 5°C change for the previous hour • Does not vary by more than 0.5°C for 12 consecutive hours • Equals the ambient temperature for 12 consecutive hours.

(Continued)

TABLE 37. (Continued)

Meteorological Variable	Screening Criteria[a]
Precipitation	• Is greater than 25 mm in one hour. • Is greater than 100 mm in 24-hours. • Is less than 50 mm in three months. (The above values can be adjusted base on local climate.)
Pressure	• Is greater than 1,060 mb (sea level) • Is less than 940 mb (sea level) (The above values can be adjusted for elevations other than sea level). • Changes by more than 6 mb in three hours.

[a] Some criteria may have to be changed for a given location.

- The percent difference between the air concentrations measured at coallocated samplers is:

$$d_i = \frac{Y_i - X_i}{(Y_i - X_i)/2} \times 100 \qquad \text{(Eq. 2)}$$

where:

d_i = the percent difference between the concentration of air toxic constituents Yi measured by the collocated monitoring station and the concentration of air toxic constituent Xi, measured by the monitoring station reporting the air quality.

- The average percent difference d_j for the monitoring period is:

$$d_j = \frac{1}{n} \sum_{i=1}^{n} d_i \qquad \text{(Eq. 3)}$$

where:

d_i = percent difference defined above, and

n = number of samples collected during the monitoring period.

- The standard deviation S_j for the percent differences is:

$$S_j = \frac{1}{n-1} \left[\left[\sum_{i=1}^{n} d_i^2 - \frac{1}{n} \left(\sum_{i=1}^{n} d_i\right)^2 \right] \right]^{1/2} \qquad \text{(Eq. 4)}$$

- The 95-percent probability limits for precision are:

Upper 95-Percent Probability Limit = $d_j + 1.96\ S_j/\sqrt{2}$ (Eq. 4)

Lower 95-Percent Probability Limit = $d_j - 1.96\ S_j/\sqrt{2}$ (Eq. 5)

- The accuracy is calculated for the monitoring period by calculating the percent difference d_i between the indicated parameter from the audit (concentration, flow rate, etc.) and the known parameter, as follows:

$$d_i = \frac{Y_i - X_i}{X_i} \times 100 \qquad \text{(Eq. 6)}$$

where:

Y_i = monitor's indicated parameter from the ith audit check, and

X_i = known parameter used for the ith audit check.

These results should then be compared with the QA/QC criteria stipulated in the monitoring plan to determine data validity.

3.6.3 Summarize Data

Monitoring data summaries should be prepared using the validated data bases as input. These meteorological and air monitoring data summaries facilitate the characterization of exposure potential at various locations and receptors of interest.

Meteorological Data Summaries

Meteorological data summaries should include at least the following:

- Listing of all meteorological parameters for the air sampling periods;
- Daytime wind rose (only for coastal or complex terrain areas);
- Nighttime wind rose (only for coastal or complex terrain areas);
- Summary wind rose;

- Summary of dispersion conditions for the sampling period (joint frequency distributions of wind direction versus wind speed category and stability class frequencies based on guidance presented in Guidelines on Air Quality Models (Revised) (U.S. EPA, July 1986);

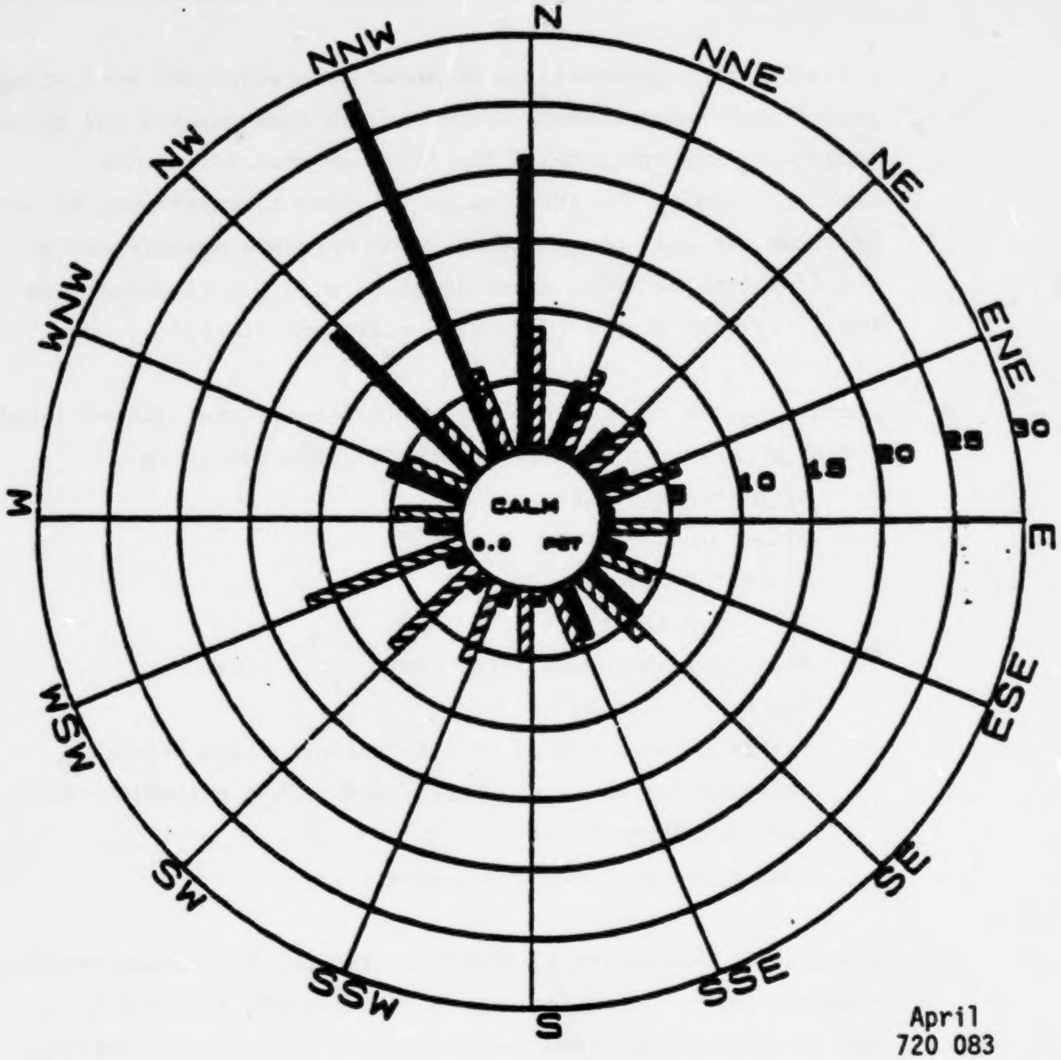
- Tabular summaries of means and extremes for temperature and other meteorological parameters; and

- Data recovery summaries for all parameters.

Meteorological listings should generally be presented on a sequential hourly basis. A 1-hour time frame is sufficient to account for any short-term temporal variability of the data. The presentation of data for periods of less than 1 hour would unduly complicate the data evaluation process, and the listings would be voluminous. For those cases in which multiple meteorological stations are used at a single site, it is desirable to list the data in adjacent columns to facilitate data comparisons.

Statistical summaries for the meteorological data should be presented monthly, seasonally, and annually, and for the entire monitoring period. For sites with diurnal wind patterns (e.g., at complex terrain or coastal areas), separate wind roses should be prepared to characterize daytime conditions and nighttime conditions, and a summary wind rose (based on all wind observations during the monitoring period) should be developed. A suggested format for wind rose data is illustrated in Figure 19.

Data recovery information should also be presented to allow for an evaluation of data representativeness. The minimum data recovery target should be 75 percent.



April
720 083

■■■■■■ Wind Direction Frequency (Percent)

////// Mean Wind Speed (Mi/Hr)

Figure 19. Example Wind Rose Format.

Air Monitoring Data Summaries

Air monitoring data summaries should include at least the following:

- A listing of concentrations measured by station and monitoring period indicating concentrations of all constituents for which monitoring was conducted. The listings should indicate detection limits for those cases in which a constituent is not detected, as well as upwind/downwind exposure classification and monitoring station operational data (e.g., sampling flow rates, station numbers, sampling start/end times);

- Summary tables of constituent-specific concentrations measured for each monitoring station, including the following:
  - Mean concentration
  - Minimum concentration
  - Maximum concentration
  - Detection limit
  - Frequency above and below detection limits
  - Number of samples
  - Number of occurrences of air concentrations exceeding selected values (e.g., health and safety criteria, ARARs and odor thresholds)
  - Upwind/downwind exposure summaries;

- A narrative discussion of sampling results, indicating problems encountered, the relationship of the sampling activity to unit operating conditions and meteorological conditions, sampling periods and times, background levels and other air emission sources, and interferences that may complicate data interpretation

- Data recovery parameters for all parameters

Air monitoring listings should be sequential and consistent with the sampling interval used (e.g., one 24-hour integrated sample to represent a 1-day period is frequently used). The listings should include flags to identify samples that exceed health/safety criteria, ARARs, and odor thresholds. Monitoring station operational data (e.g., start and stop times for sampling, sampling flow rates) should also be included with the data listings. If practical, concurrent data for the monitoring network (i.e., all stations) should be listed in adjacent columns to facilitate data comparisons.

The air monitoring data listings should also indicate the upwind/downwind classification of the monitoring station during the sampling period. Based on hourly meteorological data, the percentages of the sampling time that a station is upwind and downwind should be specified. Therefore, upwind and downwind sectors (i.e., a range of wind directions) should be defined for each monitoring station to aid in data interpretation. Figure 20 illustrates the range of wind directions over which the air monitoring stations will be downwind of an air emission source. Therefore, concentrations measured during upwind conditions can be used to characterize background conditions, and concentrations measured during downwind conditions can be used to evaluate the source-specific contributions to downwind exposures.

Plotting individual concentration points as a function of downwind frequency can improve the interpretation of data for certain situations. Such analyses are generally beneficial for sites with significant diurnal wind direction variability, especially those on complex terrain and in coastal locations. An application of this downwind frequency analysis approach is illustrated in Figure 21. Examination of the data presented in this figure indicates that air concentrations at Station A are random and not correlated with downwind frequency. However, the data for Station B appear to be linearly related to downwind frequency. Therefore, it can be concluded that the air emission source significantly affects Station B but not Station A.

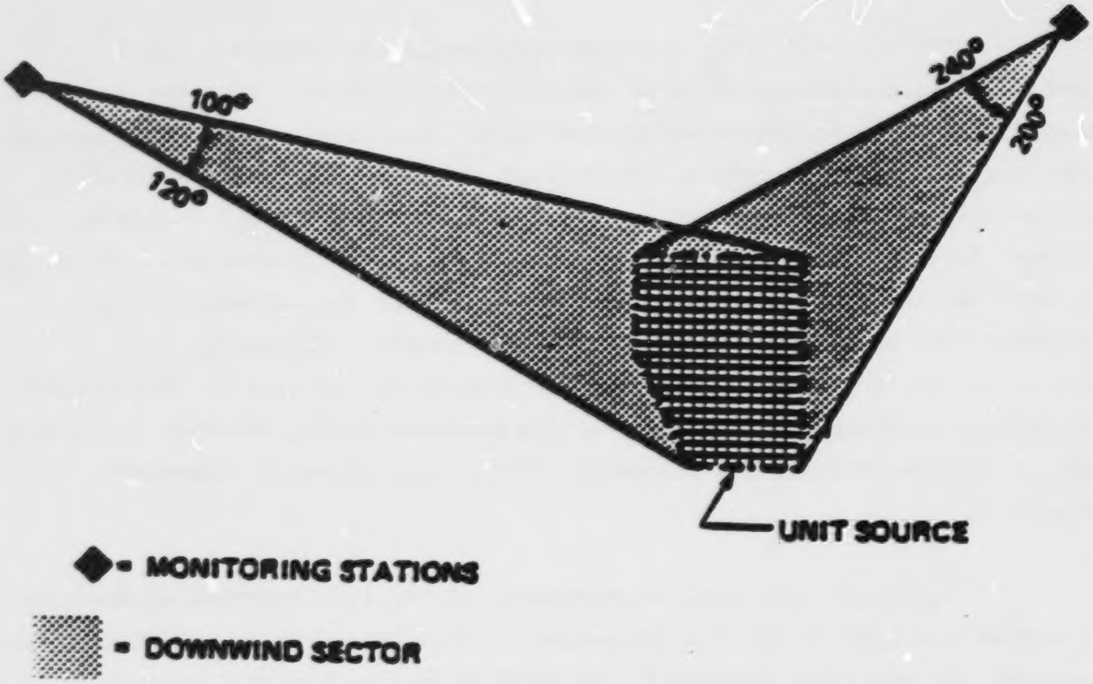

100°
120°
240°
200°
UNIT SOURCE
◆ = MONITORING STATIONS
▨ = DOWNWIND SECTOR

Figure 20. Example of Downwind Exposures at Air Monitoring Stations.

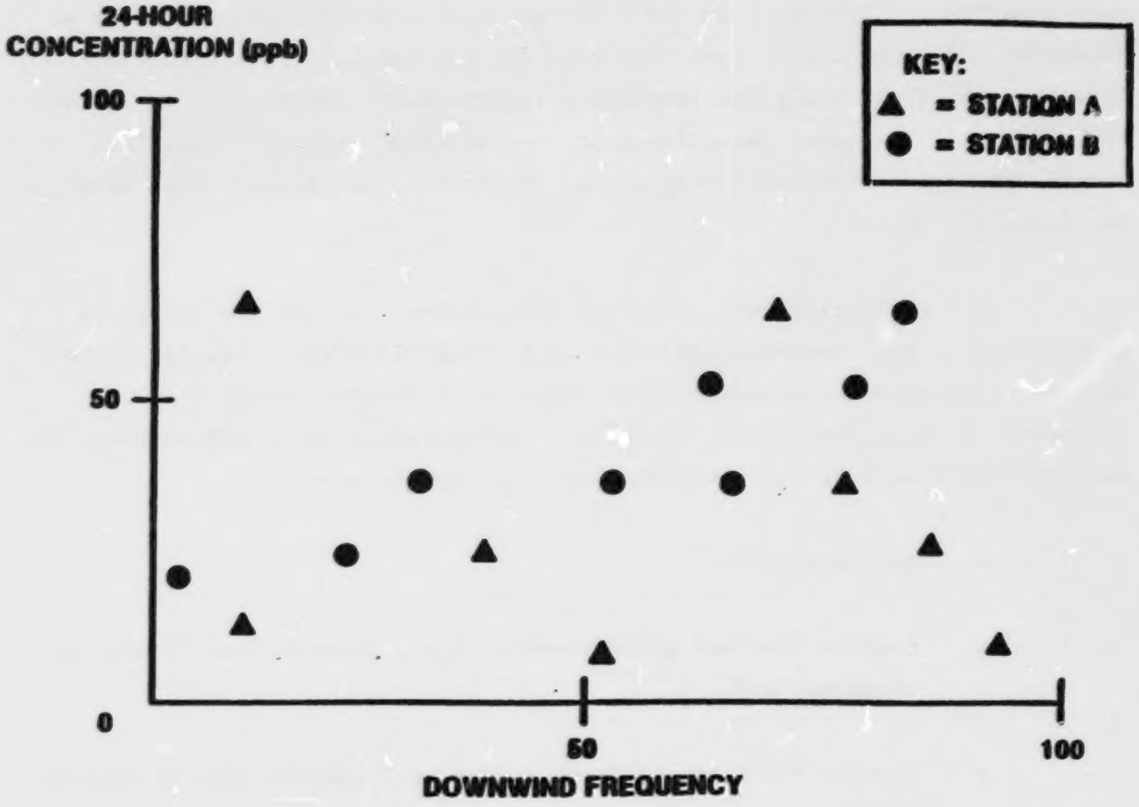


Figure 21. Example Application of Downwind Frequency Analysis.

Statistical summaries of air monitoring data should be presented monthly, seasonally, and annually, and for the entire monitoring period. In addition to concentration means and extremes, these summaries should present any other information deemed useful for the interpretation of monitoring results. Of particular interest, for example, is the frequency that sampling results are below (or above) analytical detection limits. Samples that are below detection limits can greatly complicate the computation of mean concentrations. Therefore, in the computation of mean concentrations for a Superfund APA application, concentrations for any sampling period that are less than the lower analytical detection limits should arbitrarily be assumed to be one-half the lower detection limit. Similarly, concentrations that exceed the upper detection limits should arbitrarily be assumed to be equal to the detection limit.

Air monitoring data summaries should also indicate the number of occurrences of air concentrations that exceed health/safety criteria, ARARs, and odor thresholds. Upwind/downwind exposure conditions should also be addressed in these summaries. Therefore, concentration means and extremes for each station should be presented for the following data sets:

- All samples;
- Samples that are predominantly (i.e., greater than 75 percent) downwind; and
- Samples which are predominantly (i.e., greater than 75 percent) upwind.

Data recovery information should also be presented to evaluate data representativeness. A minimum data recovery target should be 75 percent.

3.6.4 Perform Dispersion Modeling

Results of atmospheric dispersion modeling can be used to assist in the interpretation of the air monitoring results. They also can be used to augment the measured data.

Dispersion patterns derived by plotting isopleths of air concentration divided by the source emission rate for the air monitoring periods can provide information on areas of high concentrations and zones of concentration gradients. Comparison of these patterns with measured concentrations can provide additional information on areas of high concentration and a qualitative interpolation and extrapolation of the pattern of the measured concentrations.

Frequently it may not be practical to place air monitoring stations at offsite receptor locations of interest. However, it may be necessary to characterize concentrations at these locations as input to site-specific risk assessments. In these cases, dispersion patterns based on modeling results can be used to extrapolate concentrations monitored onsite to offsite locations. An example of this application is illustrated in Figure 22.

Technical recommendations regarding the conduct of dispersion modeling studies (e.g., model selection) are provided in Section 2.

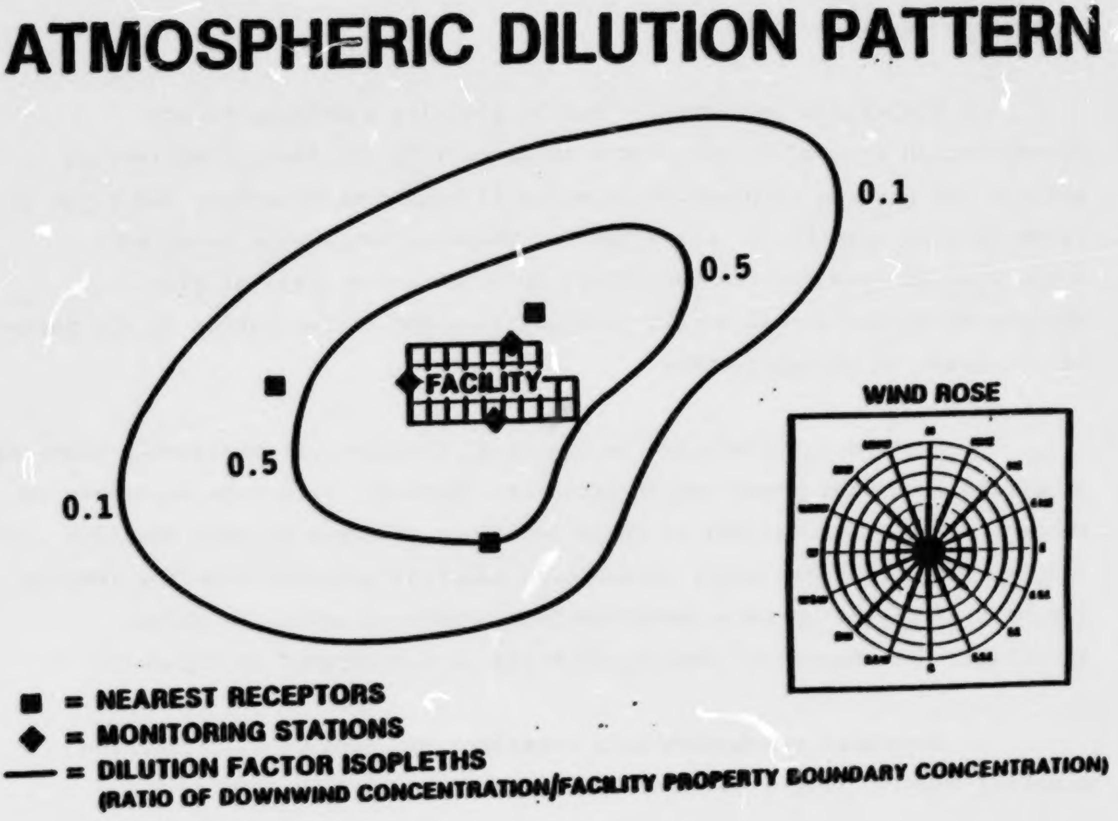

ATMOSPHERIC DILUTION PATTERN
0.1
0.5
FACILITY
0.5
0.1
WIND ROSE
■ = NEAREST RECEPTORS
◆ = MONITORING STATIONS
— = DILUTION FACTOR ISOPLETHS
(RATIO OF DOWNWIND CONCENTRATION/FACILITY PROPERTY BOUNDARY CONCENTRATION)

Figure 22. Example Atmospheric Dispersion (Dilution) Pattern.

SECTION 4
CASE EXAMPLES

4.1 OVERVIEW

Several case examples are presented in this section to demonstrate the atmospheric dispersion modeling and air monitoring procedures given in Sections 2 and 3. Example 1 illustrates a combined modeling and monitoring study in support of an RI/FS at a hypothetical wood treatment facility. The site is first described, then the five-step procedure for designing and conducting a dispersion modeling study is shown, followed by the five-step procedure for designing and conducting an air monitoring study.

Air monitoring programs are generally more dificult to design than dispersion modeling studies, so three additional case examples are shown for Superfund sites that present elements of complexity in the monitoring situations representative of actual conditions at many sites. The discussion for examples 2, 3, and 4 focuses on the design of an air monitoring network of refined monitoring techniques; it is assumed that real-time monitoring is also conducted at each site as part of the health and safety plan.

Example 2 is somewhat more complicated than the ideal monitoring scenario with a wider wind arc, fugitive sources distributed over a wider area and two other nearby emission sources, both downwind. Example 3 is characterized by an even wider wind arc, two other nearby emission sources both upwind of the Superfund site, two nearby receptors and restricted access to some potential sampling sites. Example 4 has both complex meteorology and complex terrain because of weak seasonal air patterns and the location of the site in a river valley in a heavily industrialized region.

4.2 EXAMPLE 1 - DISPERSION MODELING/AIR MONITORING APPLICATION

A screening assessment (based on emission/dispersion modeling) commensurate with Volume I recommendations was conducted to characterize hazardous air contaminants being released from an inactive wood treatment facility that had been placed on the NPL. Evaluation of these screening results indicated that it was necessary to conduct a combined dispersion modeling/air monitoring program to more accurately quantify air emissions from the site to support preparation of an RI/FS. The site is described in Section 4.2.1. The air dispersion modeling study is presented in Section 4.2.2 and the air monitoring study is presented in Section 4.2.3.

4.2.1 Site Description

The site is an inactive 12-acre wood treatment facility located in a flat inland area of the southeast. At one time, creosote and pentachlorophenol were used as wood preservatives; heavy metal salts were also used. The creosote and pentachlorophenol were disposed of in a surface impoundment. Past waste disposal practices included treatment and disposal of the metal salts in a surface impoundment and disposal of contaminated wood shavings in waste piles. The constituents of concern in the facility's waste stream include phenols, cresols, and polycyclic aromatic hydrocarbons (PAHs) in the creosote; dibenzodioxins and dibenzofurans as contaminants in pentachlorophenol; and particulate heavy metals. The potential emission sources (Figure 23) include the container storage facility for creosote and pentachlorophenol, the wood treatment and product storage areas, the surface impoundment for the creosote and pentachlorophenol wastes, and the contaminated soil area, which previously contained both the surface impoundment for treating the metal salts and the wood shavings storage area. Seepage from these waste management units has resulted in documented groundwater and surface water contamination.

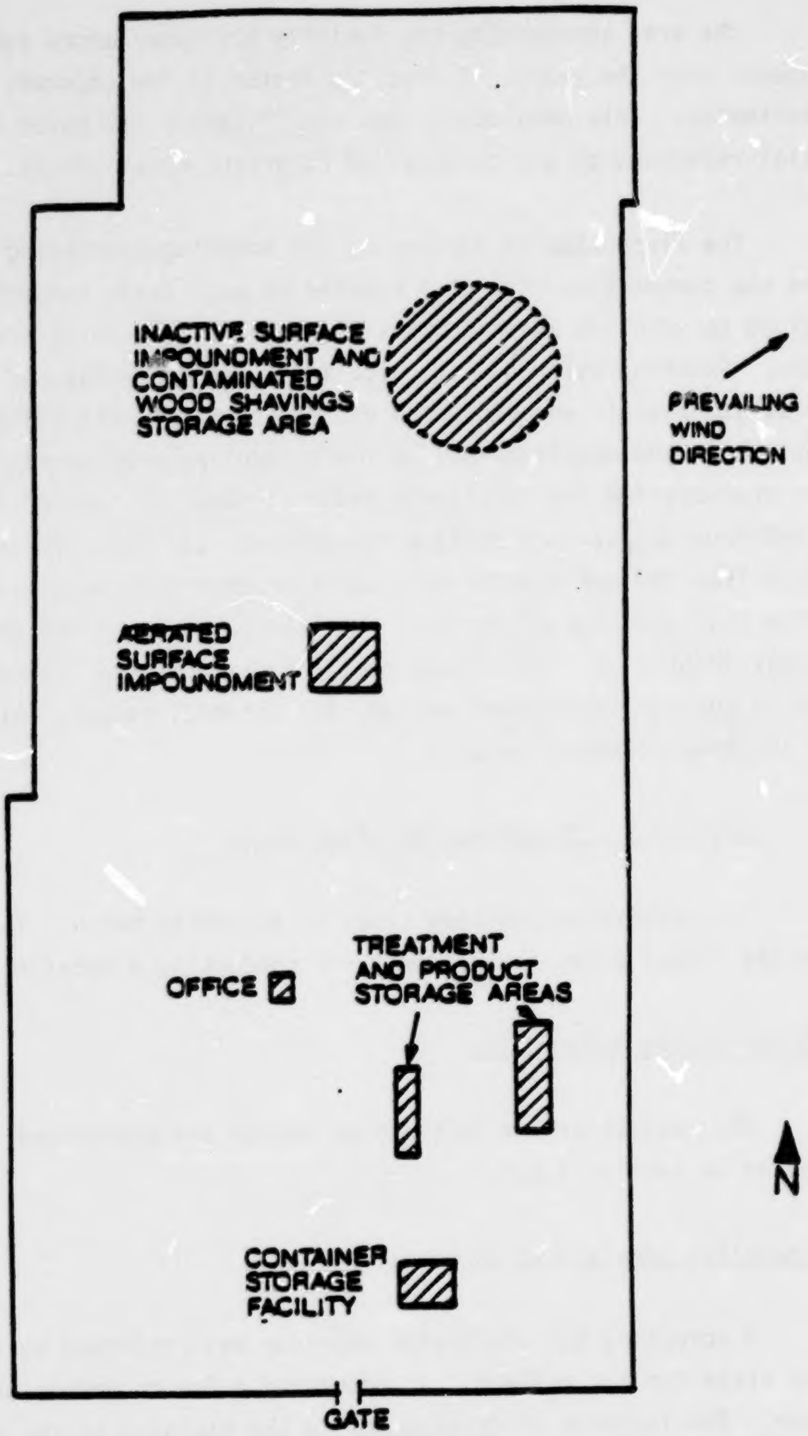

INACTIVE SURFACE IMPOUNDMENT AND CONTAMINATED WOOD SHAVINGS STORAGE AREA
PREVAILING WIND DIRECTION
AERATED SURFACE IMPOUNDMENT
TREATMENT AND PRODUCT STORAGE AREAS
OFFICE
N
CONTAINER STORAGE FACILITY
GATE

Figure 23. Example 1 Site Plan for Air Dispersion Modeling.

The area surrounding the facility has experienced substantial development over the years. A shopping center is now adjacent to the eastern site perimeter. This development has significantly increased the number of potential receptors of air releases of hazardous constituents.

The first step in developing the modeling/monitoring program was to examine the composition of wastes handled in each waste management unit were determined to identify which contaminants were likely to be present in the air releases. Existing water quality data indicated contamination of groundwater with cresols, phenol, and PAHs, and of surface water with phenols, benzene, chlorobenzene, and ethylbenzene. A field sampling program was developed to further characterize the facility's waste stream. Wastewater samples were collected from the aerated surface impoundment, and soil samples were collected from the heavy metal salt waste treatment/disposal area. Analytical data from this sampling effort confirmed the presence of the contaminants previously identified. Additional contaminants detected included toluene and xylenes in surface impoundment wastes, and arsenic, copper, chromium, and zinc in the treatment/disposal area.

4.2.2 Example 1 - Dispersion Modeling Study

The dispersion modeling study is presented below. The discussion follows the format given in Section 2 for conducting a modeling study.

Collect and Review Information

The results of the information review are summarized in the site description in Section 4.2.1.

Select Modeling Sophistication Level

A screening air dispersion modeling was performed as a part of the planning stage for the project. It addressed a few receptors at the site perimeter. The increase in development in the vicinity of the site and the associated increase in the number of potential receptors that could be exposed to air toxics releases from the site required the use of refined dispersion modeling in support of the RI/FS activities.

It was determined that the ISC dispersion model is the preferred model for this applications because:

- The sources involved resemble the types of industrial sources for which the model was developed;
- The topography is gently rolling and no major topographical obstruction exist; and
- The ISC dispersion model was employed successfully for a Superfund site similar to the one under consideration.

Develop Modeling Plan

Based on their individual emission potentials (as determined from waste analyses and confirmatory emission rate modeling) and potential for presenting health and environmental hazards, the following target compounds were selected for use in the dispersion modeling (and air monitoring):

- Volatile/semivolatile constituents
  - Toluene
  - Benzene
  - Total phenols
  - Pentachlorophenol
  - Polycyclic aromatic hydrocarbons
  - Cresols

- Particulate constituents
  - Arsenic
  - Copper
  - Chromium
  - Zinc

The target compound list was then evaluated in terms of prevalence of contaminants in each of the four sources and the information available about the activities involved with each source (see Table 38).

Emission predictive equations were identified using Volume II, Estimation of Baseline Air Emissions at Superfund Sites, for the sources involved. This included:

- Predictive lagoon equations for the inactive surface impoundment and the aerated surface impoundment for organics, and predictive fugitive dust equations for inorganics; and

- Predictive closed landfill equations for the treatment and product storage areas and the container storage facility, and predictive fugitive dust equations for inorganics.

Onsite meteorological monitoring from a 10-meter tower provided 3 months of data. These data were used to evaluate the applicability of meteorological data available from an NWS station located about 25 kilometers southeast of the site. The evaluation of wind data showed that:

- Offsite meteorological data correlate reasonably with the onsite data for the same time period. Wind direction data for offsite areas show the same pattern as those for onsite areas, i.e. an apparent small shift of about 10 to 15 degrees. The frequency distribution of wind speed and direction by stability is within about 20-30 percent.

- No major topographical features or water bodies exist between the NWS station and the site.

It was decided to use 5 years of meteorological data from the NWS station. This included both surface and upper air data.

TABLE 38. TARGET CONSTITUENTS MODELED FOR EACH OF THE SOURCES AT THE SITE

	Source			
Target Compounds	In-active Surface Impoundment	Aerated Surface Impoundment	Treatment and Product Storage Areas	Container Storage Facility
Organics - gases				
Toluene	X	X	X	
Benzene	X	X	X	
Total Phenols	X	X	X	
Pentaochlorophenol	X	X	X	X
PAHs	X	X	X	
Cresols	X	X	X	X
Inorganics-Particulate				
Arsenic	X		X	X
Copper	X		X	
Chromium	X		X	
Zinc	X		X	

Considering prevailing wind directions, source characteristics (ground level releases), population distribution in the site vicinity, and other sensitive receptor locations, it was decided to set up a grid with closely spaced receptors adjacent to the site. For modeling purposes, concentrations were averaged every 24 hours and annually.

Background concentrations for the target (indicator) compounds were obtained from a 1-month perimeter monitoring program conducted at the site. The background concentrations were obtained from upwind stations utilizing the onsite data.

Conduct Modeling

The emission inventory for the target compounds was developed based on the methodology outlined in the modeling plan. Data were input into the ISC dispersion model. Meteorological data from the NWS station were preprocessed to generate hourly data used by the ISC dispersion model. Receptor coordinates based on the receptor grid developed were input into the model.

All input data were checked and verified before the files were linked to the model. A test run was performed to verify that the model performed as specified.

Dispersion calculations were performed for each of the target compounds, and computer printout were obtained. Individual runs were made for the various target compounds.

Summarize and Evaluate Results

Results of the calculations were checked to ensure that no errors were made with the input data. Three hand calculations were made to determine the arsenic concentration at a selected receptor to verify that the model calculations are correct. Ground-level concentrations were summarized for each target compound by considering the highest and second highest 24-hour concentrations and 24-hour concentrations at sensitive receptors.

Isopleths of annual concentrations were plotted for the target compounds in a format similar to the one shown in Figure 6.

Prepare a Report

A report summarizing the results of the dispersion calculations and the detailed methodology was prepared. The calculations were based on readings obtained at receptors arranged in a rectangular grid (see Figure 24) with intervals of 100 meters for the area close to the site and on the site perimeter; 200 meters for the area from the site perimeter to about 1 kilometer from the center of the site; 500-meters for the area between 1 and 2 kilometers from the center of the site; and 1 kilometer for the area between 2 and 5 kilometers from the center of the site.

This receptor distribution was considered adequate to cover offsite publicly accessible locations and sensitive environmental receptors.

In the latter case, it was determined that most of the development took place up to about 2 kilometers from the site and mainly to the east.

The model selected was the ISC dispersion model. It was considered most suitable for this application. Both the short- and long-term calculations were performed. Key model switches included:

- Calculate concentration (=1);
- Discrete receptor system - rectangular (=1);
- Terrain elevations are read - no (=0);
- Compute average concentrations for 24 hours - yes (=1); for other averaging times - no (=0);

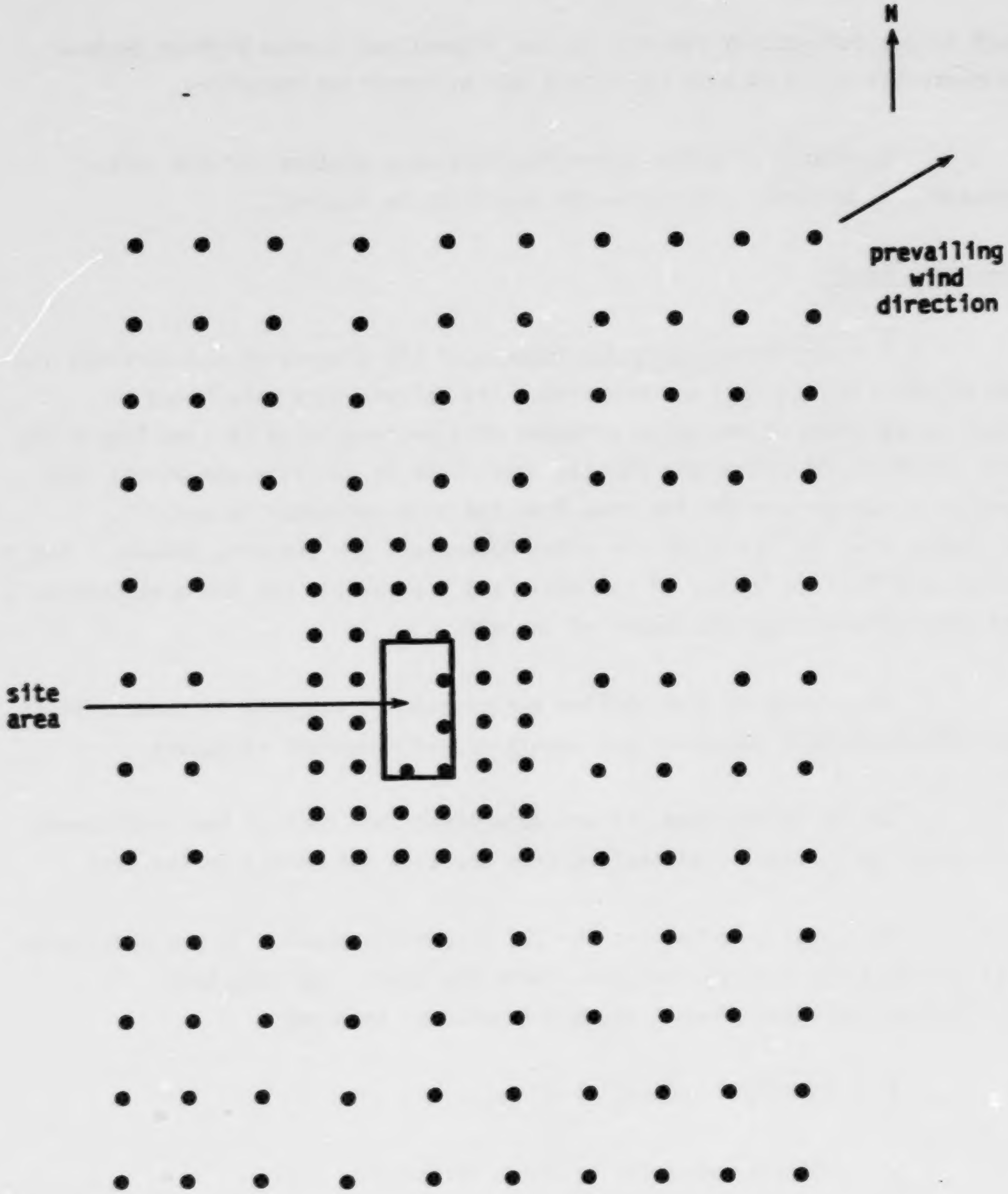

N
prevailing
wind
direction
site
area

Figure 24. Receptor Grid Close the Site.

- Print highest second highest tables - yes (=1); maximum 50 tables - yes (=1);
- Rural-urban option - rural (=1);
- Wind profile exponent values - default (=1);
- Vertical potential temperature gradient values - default (=1); and
- Program calculates final plume rise only - no (=2).

4.2.3 Example 1 - Air Monitoring Study

Collect and Review Information

The results of the information review are summarized in the site description in Section 4.2.1.

Select Monitoring Sophistication Level

A limited onsite air screening survey was first conducted to document air releases of potentially hazardous contaminants, to assign priorities to air emission sources, and to verify screening assessment modeling results and the need to conduct a monitoring program. Total hydrocarbon (THC) levels were measured with a portable THC analyzer downwind of the aerated surface impoundment, wood treatment area, and product storage area. Measurements were also made upwind of all units to provide background concentrations. The THC levels detected downwind were significantly higher than background levels. However, compound-specific results were not available from this screening approach to quantify the potential health and safety impacts associated with air emissions from the site. Therefore, a refined monitoring program to characterize releases to the air was considered appropriate.

Develop Monitoring Plan

The target analytes for the air monitoring were selected on the same basis as the target compounds for the dispersion modeling. The lists are identical since no logistical considerations precluded collecting and analyzing each of the compounds. They were:

- Volatile/semivolatile constituents
  - Toluene
  - Benzene
  - Total phenols
  - Pentachlorophenol
  - Polycyclic aromatic hydrocarbons
  - Cresols

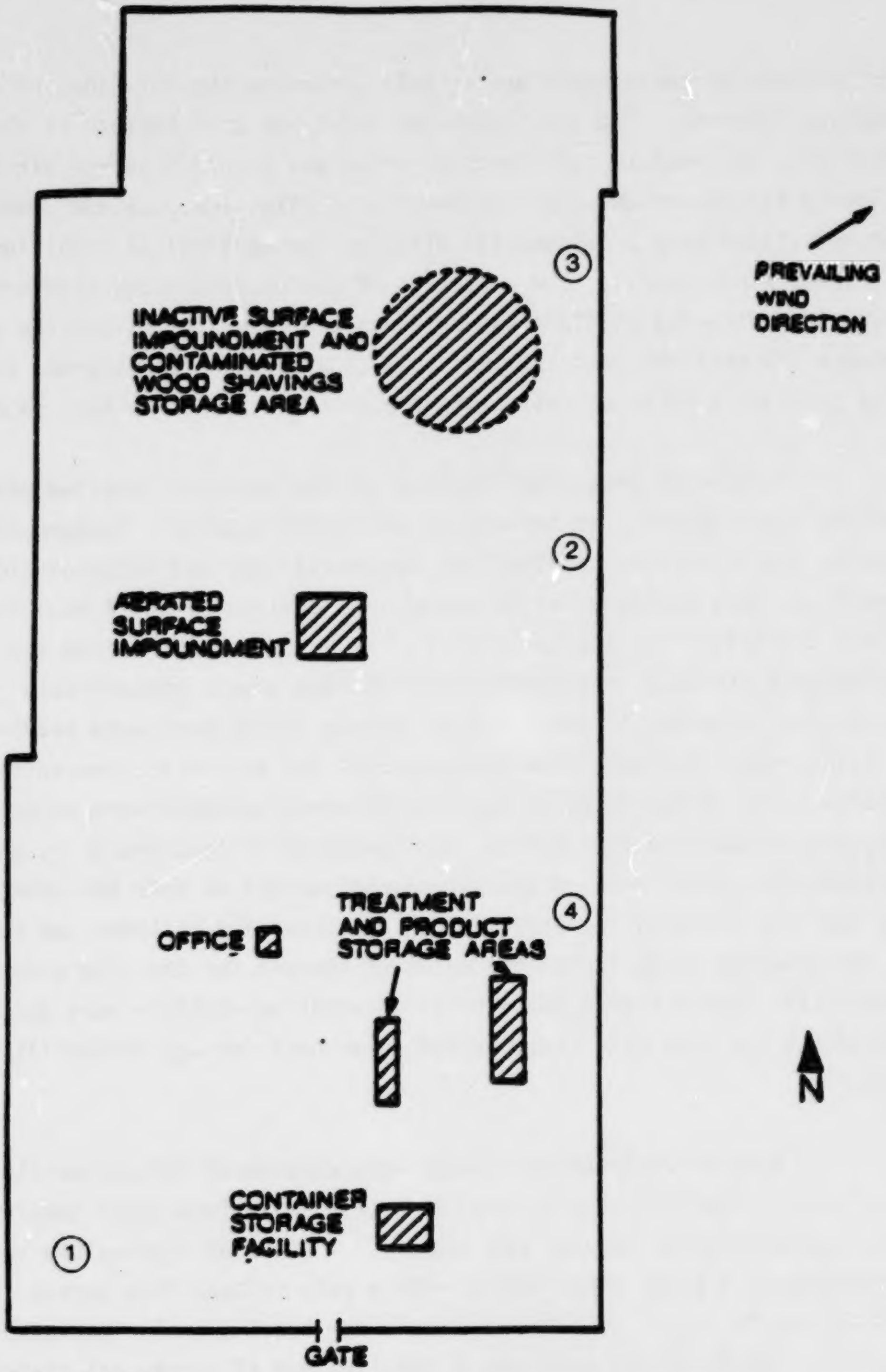
- Particulate constituents
  - Arsenic
  - Copper
  - Chromium
  - Zinc

Meteorological information is critical for designing an air monitoring program because stations must be located both upwind and downwind of the contaminant sources. Therefore, a 1-month meteorological monitoring survey was conducted at this flat-terrain site. The survey was conducted under conditions considered representative of the summer months during which air samples would be collected. Summer represented the worst-case combination of emission and dispersion conditions (i.e., light, steady winds and warm temperatures). The collected meteorological data showed that the local wind direction was from the southwest. No well-defined secondary wind flows were identified. The survey data also confirmed that one 10-meter meteorological station would be sufficient to support the air monitoring program.

The onsite meteorological survey data were used with the EPA's, Industrial Source Complex (ISC) dispersion model to estimate the worst-case air emission concentrations and to help determine the locations of the air sampling stations. The ISC dispersion model was used because of its capability to simulate conditions of point and nonpoint source air emissions. Allowing for the established southwest wind direction, maximum downwind concentrations were predicted for different meteorological conditions (e.g., different wind speeds). The selection of upwind background stations and downwind monitoring stations was based on the predicted dispersion pathways. Because the releases from the individual source areas overlapped, the model also provided a means of estimating the contamination from each source.

Figure 25 shows the locations of the selected sampling stations. Station 1 was selected as the upwind background station. Background volatile organic concentrations, particulate concentrations, and meteorological conditions were monitored at this station. Stations 2 and 4 were located at points convenient for the monitoring of volatile emissions from the surface impoundment and wood treatment/product storage areas, respectively. Station 3 was located downwind of the inactive surface impoundment/wood shavings disposal area. Releases from these sources and worst-case concentrations of volatiles and particulates at the site property boundary were documented at this site. For this application, the locations of Stations 2, 3, and 4 were adequate for characterizing the air concentrations at both the source boundary and the site property boundary (due to the proximity of these two boundaries in the downwind direction of the units of concern for the site prevailing wind direction). Three trailer-mounted air monitoring stations were used to supplement the permanent stations and to account for any variability in wind direction.

Several alternative methods were considered for air monitoring at this site. It was decided to use EPA Method TO-14 (whole air sampling using metal canisters) for benzene and toluene. A modified high-volume sampler consisting of a glass fiber filter with a polyurethane foam backup sorbent (EPA Method TO-4) was selected to sample for total phenols, pentachlorophenol, and PAHs. NIOSH Method 2001, which involves use of silica gel cartridges, was selected for the collection and analysis of cresol samples. Particulates were collected on glass fiber filters using high-volume samplers.


③
INACTIVE SURFACE IMPOUNDMENT AND CONTAMINATED WOOD SHAVINGS STORAGE AREA
PREVAILING WIND DIRECTION
②
AERATED SURFACE IMPOUNDMENT
④
OFFICE
TREATMENT AND PRODUCT STORAGE AREAS
N
CONTAINER STORAGE FACILITY
①
GATE

N = Monitoring Location

Figure 25. Example Site Plan and Air Monitoring Network.

Conduct Monitoring

The air quality monitoring was conducted over a 3-month period during the summer. Meteorological variables were measured continuously throughout the study. Air samples were taken over a 24-hour period every six days. A rigorous QA/QC program was implemented commensurate with the selected monitoring period and according to the method specified in EPA technical reference documents. Field technicians assigned to conduct multimedia environmental surveys for the RI/FS and to operate the air monitoring network. These staff were trained by an air toxics specialist. The air toxics specialist also routinely reviewed the monitoring results to evaluate data validity, to identify potential monitoring problems, and to determine the need for corrective action. He was assisted by a chemist, who performed the detailed data validation for the air toxics under consideration.

Summarize and Evaluate Results

Standard sampling/analytical methods were available for all the target monitoring compounds. However, analytical detection limits were below specific health and environmental criteria for all compounds except cresol. The high analytical detection limit for cresol--it exceeded reference health criteria--complicated data analysis. This difficulty was handled by the collection and analysis of additional waste samples. The data obtained in these analyses were subjected to emission rate modeling to determine the emission potential of cresol and thus to develop an estimate of cresol levels in the air.

Analytical results obtained during this sampling program established that fugitive air emissions significantly exceeded reference health criteria. Measures to reduce emission concentrations to a point below health criteria levels were identified.

4.3 EXAMPLE 2 - AIR MONITORING APPLICATION

This example scenario presents a monitoring situation with minimum levels of complication. The presentation primarily deals with one step of the five-step process given in Section 3 - the design of the air monitoring network. The key parameters for example 2 are listed in Table 39. The site is assumed to be in the remediation phase, with emissions arising from excavation of contaminated soils and nearby on-site stabilization. Two views of the Superfund site are given in Figure 26.

With strong seasonal winds and a small wind arc, only one 100% upwind location (#1) is necessary. Seven downwind locations (#2-#8) are in an array between the Superfund site and the adjacent wastewater treatment facility and the interstate freeway. These downwind sites are located at three radial distances from the site: 1000, 2000, and 3000 feet from the center of the remediation area. Note that the site fenceline in the downwind direction is only 1200-1300 feet from the center of the processing area. Thus, some of the downwind sites will have to be placed off the property.

The downwind monitoring locations are symmetrically arranged around the predominant wind direction axis, and are horizontally distributed (over an angle of approximate WIND ARC + 50%) to sample both the center and the edges of the emission plume from the site, i.e., to help define the horizontal extent of the plume.

Seven downwind monitoring locations were selected for this scenario to achieve the following objectives:

- Provide measurements of air concentration of target compounds as a function of distance from the remediation area, i.e., at three distances: approximately 1000, 2000, and 3000 feet;

TABLE 39. KEY PARAMETERS FOR EXAMPLE 2 - AIR MONITORING

---

1. Project Objective:

   - Measure impact on ambient air of emissions due to remediation

2. Meteorological Conditions:

   - Strong seasonal winds from the west, 5-15 mph
   - Small wind arc, 40-50°
   - Moderate temperatures, 60-80°F
   - Moderate relative humidity, 40-80% RH
   - Good historical meteorological records

3. Topography:

   - Site located in low, sandy rolling hills
   - Excavated flat terraces for emission sources
   - Approximately 100 feet elevation difference between waste processing area and lowest downhill monitoring location

4. Emission Sources Within Site:

   - Major emissions from the site are fugitive sources localized in the processing area

   - Elevated point sources exist in the processing area but are not major sources of target compounds

5. Regional Ambient Air Quality:

   - Regional ambient air quality is good

6. Other Emission Sources:

   - No industrial development or heavy vehicular traffic in the area immediately upwind of site

   - Other nearby emission sources are all downwind of the site: a petroleum refinery, a wastewater treatment facility, an interstate freeway

---

(Continued)

TABLE 39. (Continued)

7. Power, Access, and Security at Monitor Sites:

   - 115 VAC power available for meteorological station site only
   - Site fenceline in the downwind direction is only 1200-1300 feet from center of the processing area
   - Some monitoring sites will be located outside site property, but no problems with access or security are expected

8. Receptor Locations:

   - Downwind fenceline is close enough to processing area that some downwind monitoring sites must be located off the property
   - No problems with access to potential sampling sites for almost 360° around site

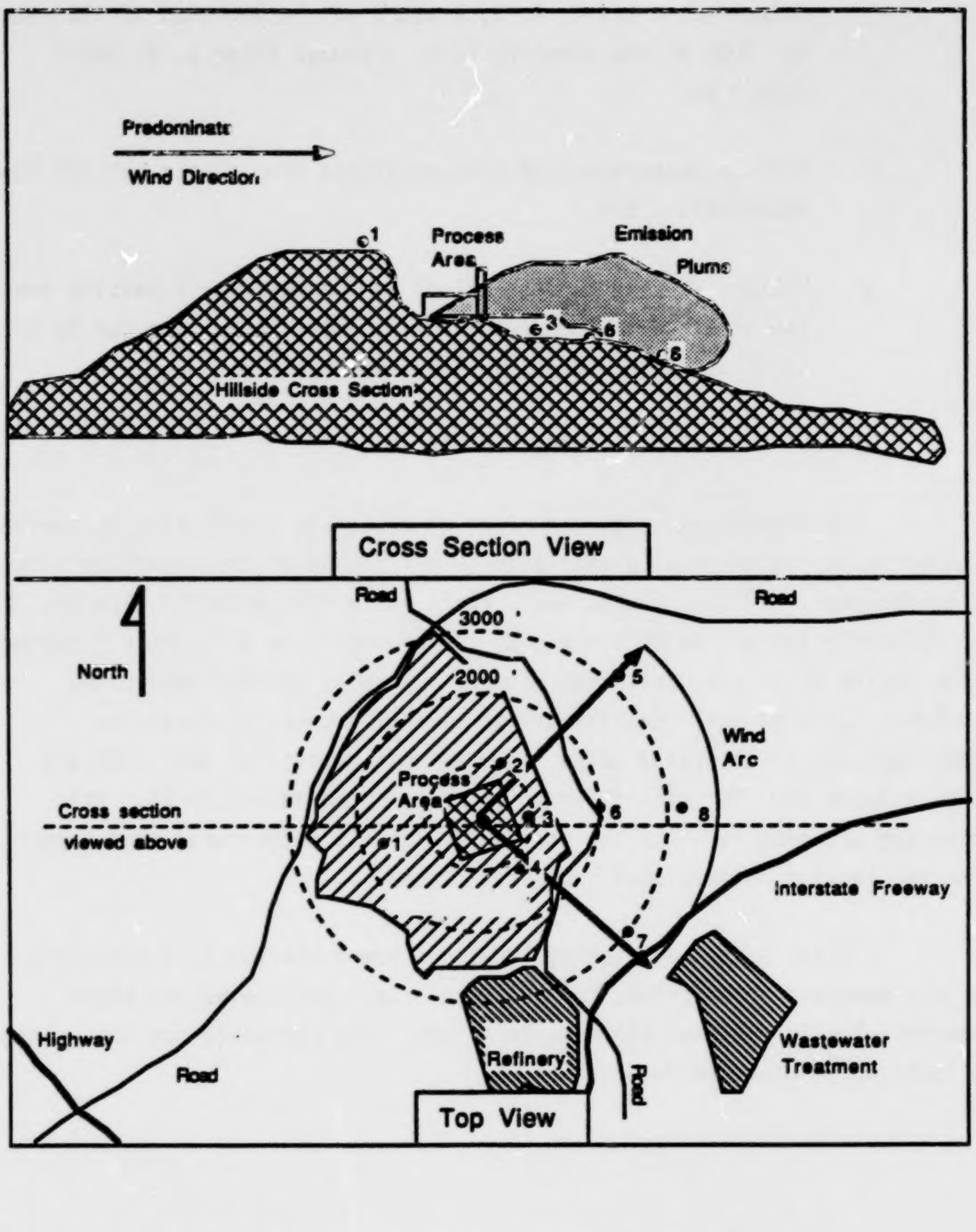

Predominate
Wind Direction
1
Process
Area
Emission
Plume
3
6
6
Hillside Cross Section
Cross Section View
Road
Road
3000 '
2000 '
North
5
Wind
Arc
2
Process
Area
Cross section
viewed above
1
3
6
8
4
7
Interstate Freeway
Highway
Road
Refinery
Road
Wastewater
Treatment
Top View

Figure 26. Two Views of Example 2 Site

- Provide measurement of air concentrations as a function of % Time Downwind, i.e., with normal variation in the wind direction, sites 2, 4, 5, 7 might not be downwind of the site for 100% of the sampling time, although sites 3, 6, and 8 should be;

- Address measurement of site emissions from points outside the remediation; and

- Measure the air concentrations in the upwind air passing over the site and in the downwind air before it is impacted by the other emission sources farther downwind.

4.4 EXAMPLE 3 - AIR MONITORING APPLICATION

This example presents a monitoring situation complicated by another emission source (a chemical plant) near to but upwind of the Superfund site, nearby receptors (office complex and a road) and a wide expected wind arc (approximately 180°). As in example 2, the presentation of example 3 centers on the design of an air monitoring network employing refined monitoring techniques for a planned remedial design employing on-site processing (stabilization) of excavated soils. The key parameters for this site are given in Table 40. The site is shown in a plot plan in Figure 27. This monitoring scenario reflects the complexity that is encountered when Superfund sites are located in developed industrial areas.

A total of ten monitoring locations are a minimum to achieve the specific monitoring objectives for this scenario: two upwind and eight downwind (plus an optional eleventh location). The rationale for the number and location is given below.

TABLE 40. KEY PARAMETERS FOR EXAMPLE 3 - AIR MONITORING

1. Project Objective:
   - Measure impact on ambient air of emissions from remediation
2. Meteorological Conditions:
   - Wind speeds are moderate, generally from the south, and 5-10 mph
   - Wind direction variability over a 24-hour period is high during this season; wind arc of approximately 180°
   - Moderate temperatures, 60-80°F
   - Moderate relative humidity, 40-80% RH
   - Good historical meteorological records
3. Topography:
   - Flat, no surface features
4. Emission Sources Within Site:
   - Major emissions are fugitive emissions localized in the processing area
   - Elevated point sources exist in processing area but are not major sources of target compounds
5. Regional Ambient Air Quality:
   - Regional ambient air is impacted by refineries and chemical plants in the region
6. Other Emission Sources:
   - A chemical plant is nearby and upwind of the site part of the time (when winds are from southwest)
   - Vehicular traffic on a road on the western perimeter of the site could be source of target compound emissions

(Continued)

TABLE 40. (Continued)

---

7. Power, Access, and Security
   - 115 VAC power is available for meteorological station site only
   - Good access for 360° around the processing area, but another source and receptors are within 1000-2000 feet of the remediation area
   - Access to the adjacent farm land was denied
8. Receptor Locations:
   - Office complex northwest of remediation area and about 2000 feet away
   - Vehicular traffic on road west of remediation area and about 2000 feet away

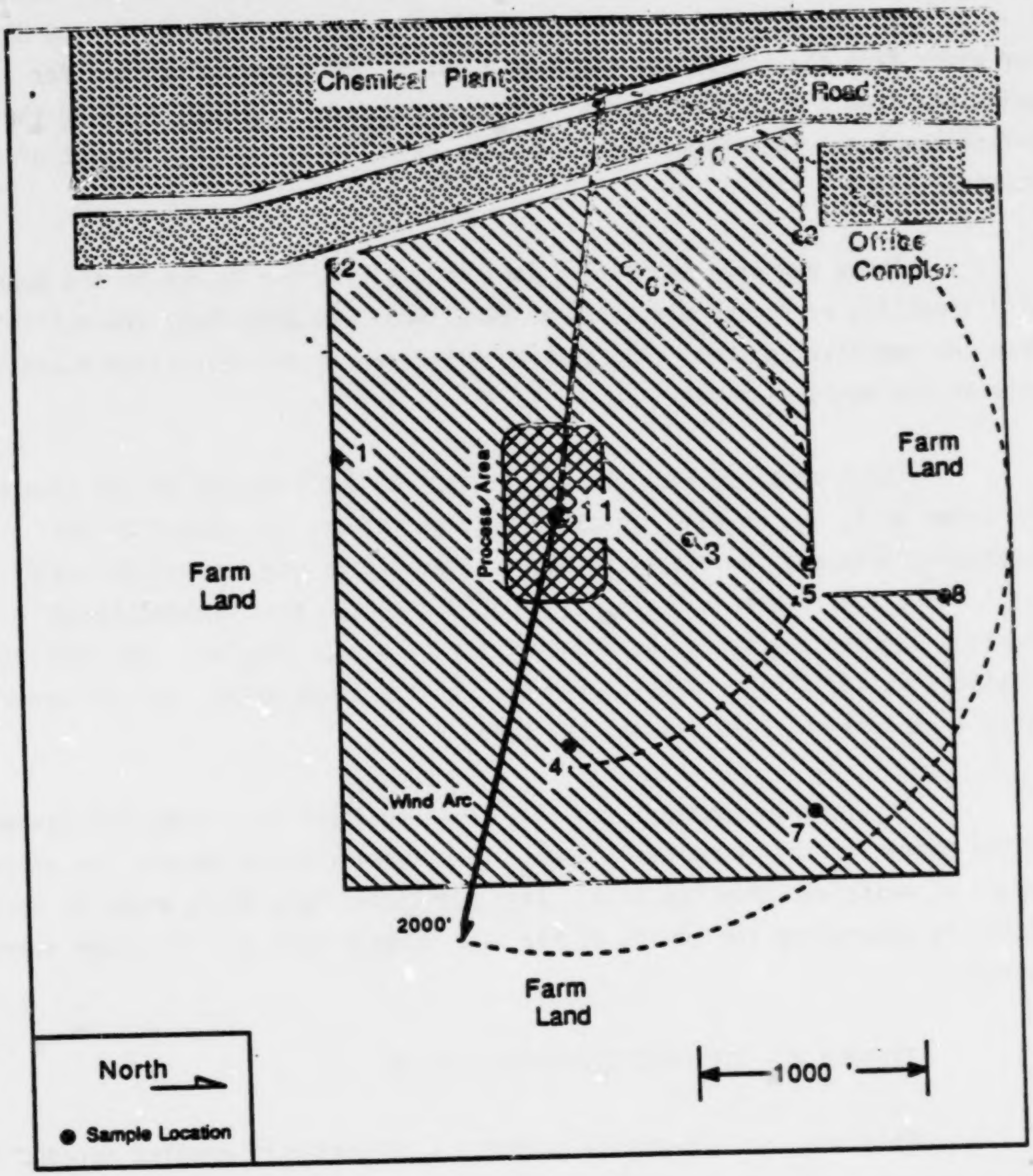

Chemical Plant
Road
Office Complex
Farm Land
Farm Land
Farm Land
Process Area
Wind Arc
2000'
1
2
3
4
5
6
7
8
9
10
11
12
North
● Sample Location
1000 '

Figure 27. Example 3 Site Plan

Monitoring locations 1 and 2 are upwind of the site and location 2 is between the Superfund site and the chemical plant. Two upwind locations are needed to help separate the impact of the other emission source. Location 1 is on the line of the mean wind direction (as are locations 3, 5, and 8). For winds from the southwest, samplers 2, 6, 9, and 10 would monitor for emissions from the chemical plant flowing across the road and reaching the office complex. Therefore, these samplers serve to isolate the impact of the chemical plant.

Three downwind monitoring locations (3, 5, and 8) are on the mean wind direction vector at distances of 500, 1000, and 2000 feet, respectively, from the remediation area. These three sites sample the dispersion along the axis of the emission plume.

Three sampling loations (6, 9, and 10) are situated on one side of the plume axis, but on wind direction vectors between the center of the processing area and the nearby receptors (the office complex and the road). Locations 6 and 10 are at distances of 1000 and 2000 feet, respectively. Location 9 is at the fenceline adjacent to the office complex. Two sampling locations (4 and 7) are on the other side of the plume axis. Two are adequate since there are no receptors on that side.

An eleventh optional sampling location might be placed just downwind of the center of the remediation area. This sampler would measure the maximum impact of emissions from the site. This additional data point might be very useful in separating the impact of the site cleanup from all the other nearby sources.

4.5 EXAMPLE 4 - AIR MONITORING APPLICATION

This monitoring scenario presents a situation of complex meteorology and topography, with the Superfund site located in a river valley in a heavily industrialized region. The key parameters of the monitoring scenario are given in Table 41 and the plan of the refinery area is shown in Figure 28.

TABLE 41. KEY PARAMETERS FOR EXAMPLE 4 - AIR MONITORING

---

1. Project Objectives:
    - Measure impact on ambient air of emissions from remediation
2. Meteorological Conditions:
    - Seasonal air movement is weak (0-2 mph) and highly variable in direction leading to extended periods of stagnant air
    - Only short-term (1-2 days) weather forecasts are available and relevant
    - Rain, cloudiness, high humidity are also seasonal; moderate temperatures 40-60°F
    - Good historical records
3. Topography:
    - Site is located in a narrow river valley in an area dominated by steep-sided hills and valleys
    - Emissions from the site are restricted by the walls of the valley up to an elevation of 1000-2000 feet above the valley floor
4. Emission Sources Within Site:
    - Major emissions within the site are fugitive sources localized in the process area
    - The processing area is long and narrow and parallel to the river
    - The site contamination includes cyclopentane. There are no other cyclopentane emission sources in the valley so that it might be useful as a tracer compound unique to the site
5. Regional Ambient Air Quality:
    - The region is characterized by heavy and diverse industrial development
    - Regional ambient air quality is poor especially under stagnant air conditions

---

(Continued)

TABLE 41. (Continued)

6. Other Emission Sources:

   - There are major emission sources in the region as well as in the river valley location of the site, e.g., a chemical plant is located directly across the river and a road to the east

7. Power, Access, and Security at Monitor Sites:

   - 115 VAC power is available at meteorological station site
   - Access to potential sampling sites is very restricted by the hilly topography and the river

8. Receptor Locations:

   - A residential area is located near the site
   - For chemical emissions that could become trapped in the river valley under stagnant meteorological conditions, workers of the Superfund site and chemical plant are potential receptors.

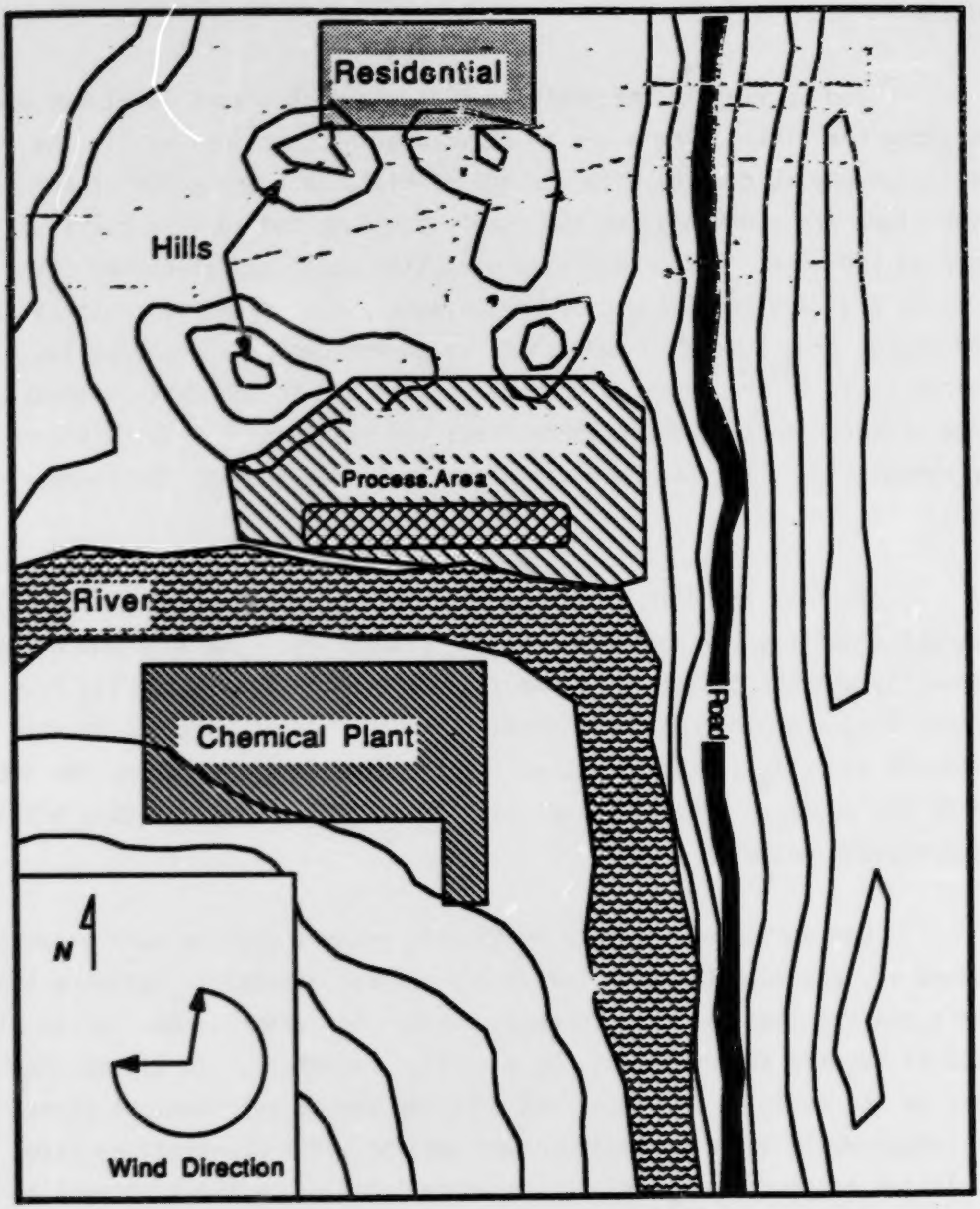

Residential
Hills
Process Area
River
Chemical Plant
Road
N
Wind Direction

Figure 28. Example 4 Site Plan

As in the two previous examples, the object is to assess off-site impacts from remediation of the site. Remediation is again assumed to involve on-site processing of the contaminated soils/waste with no thermally buoyant emissions.

The sources in the processing area are at ground level but spread out along the river. There are no structural obstructions within the area. The topography is complex with a range of hills east and south of the site, a river along the south edge of the site's boundary and rolling hills west and north of the site. Historical wind direction data and forecasted data indicate a wind direction arc of approximately 270° from the southeast and wind speeds from less than two mph to seven mph over a 24-hour period. Nearby sources exist to the south (a chemical plant) and to the east (roadway). Three receptor locations are identified; the residential area to the north of the remediation area, the chemical plant to the south, and the roadway to the east.

In this scenario it is obvious that the complex topography will interact significantly with the complex meteorology. The movement of air in the valley and the pattern of dispersion of the chemical emissions from the Superfund site would be hard to predict. Under this condition, it will be difficult to estimate the impact of the remediation emissions on the ambient air in the valley. Several alternative courses of action for this scenario are discussed below.

One option would be to modify the project goal to only measure ambient air concentrations in the valley and not attempt to estimate the site's contribution to these concentrations. For example, monitoring sites could be located around all of the potential receptors: in the residential area, on the road, on the Superfund site and around the chemical plant. Such a strategy would serve to estimate the ambient air concentrations (and inhalation exposure potential) at receptor locations without attempting to evaluate the site's contribution.

Another option would involve the use of cyclopentane as a tracer airborne chemical unique to the cleanup. In this option, ambient air concentrations of cyclopentane would be measured along with several other target compounds characteristic of the Superfund site. It would have to be established that the tracer cyclopentane could act as a surrogate for the other chemical emissions from the site. If the correlation could be established, then measurement of ambient air concentrations of cyclopentane and other target compounds at the receptor sites could be used to deduce the impact of the remediation.

Another option involves collecting or developing three-dimensional air patterns for the river valley as a function of different meteorological conditions. With this site-specific meteorological and topographical input, an air dispersion model could be calculated for the emissions from this site. The modeling results could predict the areas of maximum air concentrations in the valley to serve as guidance for the placement of sampling sites. All this should be done as input to the study design.

Choices among the options outlined above will involve review of project objectives and the resources available, e.g., budget and schedule. These choices can only be made on a case-by-case basis. Thus, the complexity of example 4 prevents a specific determination of a number and location of sampler sites.

SECTION 5
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APPENDIX A
BIBLIOGRAPHY OF AIR MONITORING METHODS

APPENDIX A

BIBLIOGRAPHY

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This manual is a comprehensive compilation of standardized methods for sampling and analysis of ambient and workplace air adopted by the APHA Intersociety Committee on Methods of Air Sampling and Analysis.

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This publication resulted from the fourth biennial Boulder Conference on environmental monitoring of air quality sponsored by the ASTM. The conference was structured to highlight several major areas of concern to environmental scientists, namely, sampling for toxic

organics in ambient, workplace, and source-related atmospheres; analyzing for important classes of pollutants such as polychlorinated biphenyls (PCBs), polynuclear aromatic hydrocarbons (PAHs), and polycyclic organic matter (POM); and measuring exposure to toxic organics in the workplace.

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Drager. May 1985. *Detector Tube Handbook*. Dragerwerk AG Lubeck. Federal Republic of Germany.

This handbook presents procedures for the use of colorimetric detector tubes for a wide range of organic and inorganic compounds. Data is provided on standard ranges of measurement, precision and accuracy, measurement principles, and cross-sensitivity.

NIOSH. February 1984. *NIOSH Manual of Analytical Methods*. NTIS PB 85-179018. National Institute of Occupational Safety and Health. Cincinnati, OH.

The NIOSH manuals contain a wealth of information on sampling and analytical procedures for a wide range of toxic organic and inorganic species. Although primarily directed at determination of worker exposure levels, these methods can quite often be applied (with minimal modifications) to the measurement of ambient concentration levels of concern in perimeter and offsite monitoring.

N.J. DEP. October 1987. Ambient Air Monitoring at Hazardous Waste and Superfund Sites. Division of Environmental Quality. Air Quality Management and Surveillance. New Jersey Department of Environmental Protection. Trenton, NJ 08625.

This document contains a master table of sampling and analytical methods for ambient air monitoring listed by compound name. Key information on species includes recommended sampling and analytical methods, the applicability of each method, performance data, and reference information.

SCAQMD. October 1985. Guidelines for Implementation of Rule 1150.1. South Coast Air Quality Management District. Engineering Division. El Monte, CA 91731.

This document contains standard operating procedures for the collection of ambient air samples at landfill perimeters and for instantaneous landfill surface monitoring, as well as analytical procedures for a wide range of toxic volatile organic compounds.

U.S. EPA. April 1984. Compendium of Methods for the Determination of Toxic Organic Compounds in Ambient Air. EPA-600/4-84-041. Office of Research and Development. Research Triangle Park, NC 27711.

Specific Standard Operating Procedures (SOPs) contained in this compendium are as follows:

Method TO-1	Method for the Determination of Volatile Organic Compounds in Ambient Air Using Tenax Adsorption and Gas Chromatography/Mass Spectrometry (GC/MS). (Applicable to volatile, non-polar organic compounds.)

Method TO-2	Method for the Determination of Volatile Organic Compounds in Ambient Air by Molecular Sieve Adsorption and GC/MS. (Applicable to highly volatile, nonpolar organic compounds.)
Method TO-3	Method for the Determination of Volatile Organic Compounds in Ambient Air Using Cryogenic Preconcentration Techniques and Gas Chromatography with Flame Ionization and Electron Capture Detection. (Applicable to volatile, nonpolar organic compounds.)
Method TO-4	Method for the Determination of Organochlorine Pesticides and Polychlorinated Biphenyls in Ambient Air.
Method TO-5	Method for the Determination of Aldehydes and Ketones in Ambient Air Using High Performance Liquid Chromatography.
Method TO-6	Method for the Determination of Phosgene in Ambient Air Using High Performance Liquid Chromatography.
Method TO-7	Method for the Determination of N-Nitrosodimethylamine in Ambient Air Using Gas Chromatography.
Method TO-8	Method for the Determination of Phenol and Methylphenols (Cresols) in Ambient Air Using High Performance Liquid Chromatography.
Method TO-9	Method for the Determination of Polychlorinated Dibenzo-p-dioxins (PCDDs) in Ambient Air Using High-Resolution Gas Chromatography/High-Resolution Mass Spectrometry (HRGC/HRMS).

Method TO-12 (Draft) Method for the Determination of Non-Methane Organic Compounds (NMOC) in Ambient Air Using Cryogenic Preconcentration and Direct Flame Ionization Detection (PDFID).

Method TO-14 Determination of Volatile Organic Compounds (VOCs) in Ambient Air Using SUMMA Passivated Canister Sampling and Gas Chromatographic Analysis.

U.S. EPA. September 1983. Characterization of Hazardous Waste Sites - A Methods Manual: Volume II, Available Sampling Methods. EPA-600/4-83-040. NTIS PB 84-126929. Office of Solid Waste. Washington, DC 20460.

This volume is a compilation of sampling methods suitable to address most needs that arise during routine waste site and spill investigations. Twelve methods are presented for ambient air, soil gases and vapors, and headspace gases.

U.S. EPA. September 1983. Characterization of Hazardous Waste Sites - A Methods Manual: Volume III, Available Laboratory Analytical Methods. EPA-600/4-83-040. NTIS PB 84-126929. Office of Solid Waste. Washington, DC 20460.

This volume provides bench-level guidance for the preparation of hazardous waste, water, soil/sediment, biological tissue, and air samples, and methods that can be used to analyze the resultant digests/extracts of 244 of the substances listed in the RCRA permit regulations.

U.S. EPA. February 1986. Measurement of Gaseous Emission Rates from Land Surfaces Using an Emission Isolation Flux Chamber: User's Guide. EPA-600/8-86-008. Environmental Monitoring Systems Laboratory. Las Vegas, NV 89114.

U.S. EPA. December 1987. Development of Collection Methods for Semivolatile Organic Compounds in Ambient Air. EPA-600/4-87-042. Environmental Monitoring Systems Laboratory. Research Triangle Park, NC 27711.

U.S. EPA. July 1983. Standard Operating Procedures for the Preparation of Standard Organic Gas Mixtures in a Static Dilution Bottle. RTP-SOP-EMD-012. Environmental Monitoring Systems Laboratory. Research Triangle Park, NC 27711.

U.S. EPA. November 1981. Standard Operating Procedures for the Preparation of Tenax Cartridges Containing Known Quantities of Organics Using Flash Vaporization. RTP-SOP-EMD-011. Environmental Monitoring Systems Laboratory. Research Triangle Park, NC 27711.

U.S. EPA. November 1981. Standard Operating Procedures for the Preparation of Clean Tenax Cartridges. RTP-SOP-EMD-013. Environmental Monitoring Systems Laboratory. Research Triangle Park, NC 27711.

U.S. EPA. January 1984. Standard Operating Procedures for Sampling Gaseous Organic Air Pollutants for Quantitative Analysis Using Solid Adsorbents. RTP-SOP-EMD-018. Environmental Monitoring Systems Laboratory. Research Triangle Park, NC 27711.

U.S. EPA. July 1985. Draft Standard Operating Procedures No. FA112A - Monitoring for Gaseous Air Pollutants Using the Gilian LFS Model 113 Dual Mode Air Sampling Pumps. Environmental Monitoring and Compliance Branch, Environmental Services Division, Region VII. Kansas City, KS 66115.

U.S. EPA. June 1984. Standard Operating Procedures for the GC/MS Determination of Volatile Organic Compounds Collected on Tenax. RTP-SOP-EMD-021. Environmental Monitoring Systems Laboratory. Research Triangle Park, NC 27711.

U.S. EPA. August 1983. Development of Protocols for Ambient Air Sampling and Monitoring at Hazardous Waste Facilities: Methods Summary Report. Office of Solid Waste. Land Disposal Branch. Washington, DC, 20460.

U.S. EPA. 1984. Field Standard Operating Procedures for Air Surveillance. FSOP #8. Office of Emergency and Remedial Response. Washington, DC 20460.

U.S. EPA. 1983. Air Pollution Training Institute Course 435: Atmospheric Sampling. EPA-450/2-80-004. Environmental Research Center. Research Triangle Park, NC 27711.

U.S. EPA. November 1980. Ambient Monitoring Guidelines for Prevention of Significant Deterioration (PSD). EPA-450/4-80/012. NTIS PB 81-153231. Office of Air Quality Planning and Standards. Research Triangle Park, NC 27711.

U.S. EPA. June 1983. Technical Assistance Document for Sampling and Analysis of Toxic Organic Compounds in Ambient Air. EPA-600/4-83-027. NTIS PB 83-239020. Office of Research and Development. Research Triangle Park, NC 27711.

U.S. EPA. 1977. Quality Assurance Handbook for Air Pollution Measurement Systems: Volume II, Ambient Air Specific Methods. EPA-600/4-27-027a. Environmental Monitoring Systems Laboratory. Research Triangle Park, NC 27711.

U.S. GSA. 1987. Code of Federal Regulations, Title 40, Part 50, Appendices A-G and J. Office of the Federal Register. Washington, DC 20402.

The listed appendices to 40 CFR 50 contain EPA Reference Methods for the sampling and analysis of SO_2, TSP, CO, O_3, NO_3, Pb, and PM-10 in ambient air.

APPENDIX B

EXCERPT
FROM
TECHNICAL ASSISTANCE DOCUMENT
FOR
SAMPLING AND ANALYSIS
OF
TOXIC ORGANIC COMPOUNDS
IN AMBIENT AIR
(U.S. EPA, JUNE 1983)

United States
Environmental Protection
Agency

Environmental Monitoring
Systems Laboratory
Research Triangle Park NC 27711

EPA-600/4-83-027
June 1983

Research and Development

EPA

Technical Assistance Document for Sampling and Analysis of Toxic Organic Compounds in Ambient Air

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SPECIFICATION OF QUALITY ASSURANCE PROTOCOLS

Overview

The term quality assurance (QA) refers to an overall system designed to monitor, document, and control the technical performance of a program. While the need for good QA protocols is widely recognized, the design and implementation of these protocols is frequently treated as a secondary part of the overall monitoring program. If the QA protocols for a monitoring program are to serve a useful purpose, they must (a) be readily implemented within the cost and time constraints of the program, (b) be appropraite in terms of providing useful control of technical performance, and (c) be well understood by the project personnel. Preparation of the QA plan for a monitoring program should be undertaken after the sampling strategy and sampling and analysis methods have been defined. This section of the TAD describes the important aspects of QA to be addressed prior to implementation of the monitoring program. A more detailed discussion of specific QA approaches for various sampling and analysis methods is given in Section 4.

A simplified view of an overall QA system is given in Figure 4. QA activities to be specified in the program plan are given in Table 5. The QA management function monitors and controls the various QA efforts including (a) design of the QA system prior to program implementation, (b) sampling, (c) analysis, and (4) data reduction. The functions of QA management as well as the specific QA requirements for sampling, analysis, and data reduction are discussed in the following sections of the TAD.

A series of volumes entitled Quality Assurance Handbook for Air Pollution Measurement Systems(7), available from EPA in Research Triangle Park, serves as a useful detailed guidance document in the QA area. In particular Volume I - Principles, and Volume II - Ambient Air Specific Methods may be useful in the field of toxic organic monitoring. Specific guidance for preparation of QA plans is provided in another EPA document(8). QA practices are also discussed in Methods of Air Sampling and Analysis(4).

QA Management

The functions and responsibilities of QA management are a critical part of the overall monitoring program. These functions and responsibilities are listed in Table 5.

Designing a QA system involves specification of QA requirements for each aspect of the program, preparation of a program QA manual describing these requirements, and specification of auditing and other control procedures for ensuring proper implementation of the QA system. Although the design of the QA system for a specific program is the responsibility of QA management, input from the technical personnel responsible for implementing the program is required. Technical personnel must identify areas of technical performance requiring validation, documentation, or control, estimate costs for implementation of specific quality control functions, and critically evaluate QA documents (e.g., the program QA manual) prepared by QA management. Document control involves (a) specification of revision numbers and dates on QA manuals and related materials, (b) inspection and storage of calibration and maintenance logbooks for field and laboratory instrumentation, (c) inspection and control of laboratory record notebooks, and (d) control of chain of custody forms documenting sample deposition.

QA management is responsible for the evaluation of QA data in a timely manner. Failure to review the data immediately prevents implementation of timely corrective action procedures and may result in poor data quality.

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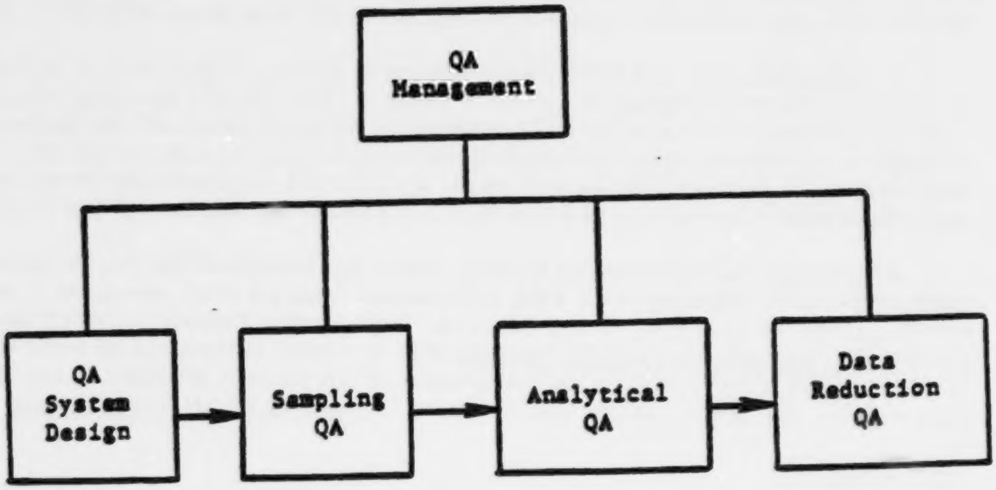
QA Management
QA System Design
Sampling QA
Analytical QA
Data Reduction QA

Figure 4. Quality assurance organization

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Table 5. Quality Assurance (QA) Activities to be Specified in Program Plan

QA Management

- QA System Design
- Document Control
- Data Evaluation and Storage
- Audit Procedures
- Corrective Action
- QA Reports to Program Management
- Training

Sampling QA

- Site Selection
- Instrument Calibration and Maintenance
- Collection of Routine Quality Control Samples
- Data Recording
- Sample Labeling, Preservation, Storage and Transport
- Chain of Custody Procedures

Analytical QA

- Method Validation Requirements
- Instrument Calibration and Maintenance
- Quality Control Sample Analysis
- Data Recording

Data Reduction QA

- Merging Sampling and Analysis Data Files
- Storage of Raw and Intermediate Data
- Data Validation

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Audit procedures include both performance and system audits. A performance audit involves introduction of a reference sample (blank, spike, standard reference material, etc.) into the analysis system in a blind fashion with subsequent assessment of the data. System audits involve a review of program documentation such as record notebooks, data files, and instrument logbooks to assess whether or not the QA system is operating properly.

In many cases data review or audit procedures will result in the need for corrective action. Corrective action may involve repeating certain aspects of the work or simply providing more detailed documentation for work already performed. In either case QA management will be responsible for documenting the need for, type of, and implementation of corrective actions.

QA management is responsible for providing scheduled as well as nonscheduled reports to program management. Scheduled reports include descriptions of the QA system prior to program implementation, QA data reports, and audit reports. Unscheduled reports generally describe corrective actions required and the impact of these actions on the program.

A final responsibility of QA management is to provide training to technical personnel. In particular, personnel need to be given a detailed view of the QA system and their responsibilities for its implementation.

Sampling Quality Assurance

Aspects of sampling to be addressed in the QA plan are shown in Table 5. Site selection considerations have been discussed in the section on sampling strategy development. However, the QA plan should specify factors which could result in a modification of the siting plan during the course of the monitoring effort (e.g., changes in source location or characteristics) and provisions for documenting any such modifications.

Instrument maintenance and calibration procedures should be specified to the extent possible in the QA plan. Any maintenance or calibration activity, scheduled or nonscheduled, should be recorded in an appropriate logbook in order to determine any effects on the data obtained. Typical calibration data obtained should include:

- Flow measurements
- Volume measurements
- Temperature measurements
- Pressure measurements
- Determination of response factors, precision, and accuracy for continuous monitors using span gases and zero gases.

In general the QA plan should specify routine calibration checks at several time points during the program.

Quality control samples to check overall system performance may include replicate or split samples, spiked samples, standard reference materials, blanks, and backup samples (e.g., series impingers or resin cartridges). Split or replicate samples are useful checks on sampling and analysis precision and should be included with each group of samples. Field blanks, in which the sampling activity is duplicated exactly except that no air is sampled, should also be routinely collected. Backup samples should be collected whenever the recovery performance of a particular sampling medium has not been documented or is subject to wide variations depending on ambient conditions. Spiked samples should be included wherever an accurate spiking procedure is available, provided that the spiked material reasonably simulates the physical and chemical state of the native material.

Standard reference materials (SRMs) for organic analysis are rather sparse. The National Bureau of Standards (NBS) has certified an urban dust (SRM 1649) for selected polynuclear aromatic hydrocarbons and various gas suppliers will prepare certified standards of many organic components as dilute gas mixtures. These gas mixtures should be checked against NBS standard reference materials (e.g., propane in air) to ensure accuracy of the gas mixture. Routine calibration of continuous monitors using these certified gas mixtures is highly advisable. SRMs containing selected organic compounds at trace levels in air or nitrogen are presently being developed and should be available in the near future from NBS.

Data recording procedures to be specified in the sampling QA plan include (a) periodic readings of the temperature, flow, volumes, and other parameters, (b) documentation of meteorological conditions at appropriate time points, (c) documentation of instrument operating variables (e.g., resin cartridge number), (d) documentation of any upset conditions such as sudden leakage or pressure surges, and (e) documentation of calibration or maintenance activities. A logbook for the overall sampling program in which sampling descriptions, meteorological data, and upset conditions are documented should be maintained. In addition a sampling data sheet, such as the example in Figure 5, should be prepared for each sample or set of samples in which the periodic readings and instrument parameters are recorded. Certain measurements such as filter numbers and weights or impinger volumes which are required for analytical purposes can be recorded on a separate sheet with provisions for recording subsequent analytical data on the same sheet. Separate maintenance and calibration logbooks should be maintained for each instrument. In most cases, sampling data forms specific for a given program must be prepared because of differences in the sampling design between programs.

Sample labeling, preservation, storage, and transport procedures should be specified in the QA plan and these procedures should be carefully explained to field personnel prior to sampling to ensure proper implementation. Sample labels, prepared in advance, should include sufficient information to associate the sample with a particular data sheet as well as the overall program record notebook. In general each sample should be given a unique identification number with a prefix describing the type of sample.

Sample preservation, storage, and transport procedures must be appropriate for the type of analyses required. Particulate samples generally should be placed in air tight containers and stored in the dark to minimize analyte degradation. Resin cartridges and impingers generally require more attention, because of analyte instability in the matrix, and should be shipped to the laboratory for analysis within a relatively short time period (e.g., a few days). These sample types should be placed in airtight, glass containers and stored at subambient temperatures until analysis. Exposure to solvents must be avoided for resin cartridges during all stages of handling in order to avoid sample contamination.

Chain of custody forms are required for certain programs having direct legal implications. The objective of the chain of custody procedures is to document the movement of a sample from collection until analysis to ensure its integrity. A typical chain of custody form is shown in Figure 6. Formal chain of custody requirements place a substantial burden on the field as well as laboratory personnel and should be employed only

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Sample I.D.	Sample Description	Date	Start Time	Stop Time	Location	Flow Rate, liter/min.		Atmospheric Pressure mmHg	Temp. °C	Operator	Calibration Data Reference	Comments
						Init.	Final					

Figure 5. Typical sampling data sheet

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CHAIN OF CUSTODY RECORD

Sample Number: ______________________

Shipper Name: ______________________

Address: ______________________
number street city state zip

Collector's Name ______________ **Telephone:** (___) ______________
signature

Date Sampled ______________ **Time Sampled** __________ **hours** __________

Type of Process Producing Waste ______________________

Field Information ______________________

____

____

Sample Receiver:

1. ______________________
name and address of organization receiving sample

2. ______________________

3. ______________________

Chain of Possession:

1. ______________ ______________ ______________
signature title inclusive dates

2. ______________ ______________ ______________
signature title inclusive dates

3. ______________ ______________ ______________
signature title inclusive dates

Figure 6. Typical Chain of Custody Form

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when the program objectives specifically require such measures. However, if the data obtained are to be used in litigation, the use of chain of custody procedures is mandatory.

Analytical Quality Assurance

Aspects of the analytical work to be addressed in the QA plan include:

- Method validation requirements
- Instrument maintenance and calibration
- Quality control sample analysis
- Data recording.

Most monitoring programs will use new methods or modifications of existing methods to some extent. The QA plan must address the validation requirements for each of these methods. Typical requirements will include determination of precision, accuracy, detection limit, and specificity through the analysis of laboratory standards, and whenever possible, representative samples. The validation requirements should be appropriate for the program objectives and should simulate the actual sampling and analytical situation as nearly as possible. Validation data should be included as part of the monitoring report and method writeups and any limitations of the data in terms of defining the performance characteristics under the actual use conditions should be documented.

Instrument maintenance and calibration requirements for laboratory instruments will be similar to those for field instruments, including the need to document any activities of this type. To the extent possible calibration and preventive maintenance schedules should be included in the QA plan. The format for recording calibration data (e.g., injection of standards of known concentration) should be specified prior to initiation of the monitoring effort.

Quality control samples for evaluating analytical performance should include blanks, spiked process blanks, spiked samples, standard reference materials, and replicate (or split) samples. Standard reference materials and replicate or split samples should generally be included as part of field QA and need not be additionally included at the analysis stage. However additional blanks, spiked process blanks, and spiked samples should be included at the analysis stage since problems with sample instability and contamination during sampling storage or shipment can be determined separately from laboratory related problems. Both spiked process blanks and spiked samples should be included since this practice allows matrix effects to be distinguished from analytical losses.

Data recording requirements during analysis require a great deal of attention to ensure that all necessary raw data are available for inspection should unexpected results occur. The advent of computerized data handling tends to "hide" raw data from the analyst. Hence the QA plan should specifically state which raw data are to be recorded, the manner of presentation, and storage procedures. Laboratory data notebooks should include all raw data or a clear reference as to where the data are recorded (e.g., 9-track magnetic tape, etc.), equations used in performing intermediate calculations, and final results. Equations used for calculations, including units for all parameters, should be presented as part of the method writeups or program QA plan.

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Data Reduction Quality Assurance

Since sampling and analytical data processing occurs independently, in most cases, the QA plan should address the manner in which data from the two activities are to be treated and validated during the reduction process. The actual presentation of data is described in the following portion of the TAD and will not be discussed here.

Aspects of data reduction to be treated in the QA plan are shown in Table 5. The extent of documentation and verification required will be greatly dependent on the program objectives, the nature of the raw data, and the complexity of the computational process.

DEFINITION OF DATA REPORTING FORMAT

Many air monitoring programs are undertaken without prior definition of the data reporting format. In some cases this appraoch is justified because of the unexpected nature of the data obtained (e.g., unexpected compounds detected or previously unknown sources identified). However, to the extent possible the format for data presentation should be defined prior to initiation of the monitoring effort. This practice helps to identify limitations on the available data and further clarifies the extent to which technical and management or policy personnel understand the program objectives. Stern's Air Pollution series(9) contains an excellent discussion of procedures for analyzing and presenting air quality data.

The optimal format for data presentation obviously is highly dependent on the program objectives and the quantity of data obtained. In cases where only a few data points are obtained around a point source (e.g., a hazardous waste landfill) tabular presentation of data (compound concentrations at each site) may be appropriate. However, in most monitoring situations the quantity and complexity of the data set will require graphical presentation. This type of data format requires definition of the important variables to be considered (e.g., source locations, sampling times, sampling sites, meteorological effects, etc.). Statistical methods for evaluating correlation between the important variables are usually required to obtain meaningful conclusions from the data set. Typical methods for statistically evaluating and displaying air quality data are given in Stern's book(9) and therefore are not presented here.

SAFETY CONSIDERATIONS

Safety considerations in air monitoring are similar to those for other chemically related occupations but should be considered for each air monitoring program since unusual hazards may be present in these situations. A discussion of general safety considerations is available(4). Potential safety hazards can be subdivided into the following broad categories:

- Chemical hazards
- Electrical equipment
- Mechanical equipment.

Chemical hazards include toxic chemicals such as carcinogenic compounds, corrosive chemicals such as concentrated acids or bases, and explosive hazards such as

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compressed gases. Protective equipment should be employed to minimize direct exposure to such hazards. Since most air monitoring programs require working with concentrated standards of toxic organic compounds, special emphasis should be placed on minimizing exposure to these materials. Programs involving investigation of concentrated or potentially concentrated sources of hazardous organic compounds require additional safety protocols to protect workers in the field as well as laboratory workers who could be unexpectedly exposed to concentrated samples collected at such sites.

Hazards from corrosive chemical, compressed gases, glassware, mechanical equipment, and electrical equipment are presented in the reference given above(4) and do not require special emphasis here. However, these hazards should be addressed in the monitoring plan.

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QUALITY ASSURANCE PROCEDURES

The purpose of this part of the TAD is to address quality assurance and related needs specific for the sampling and analysis approaches described above. The overall QA requirements of ambient air monitoring programs have been described in Section 3 of the TAD and references therein(7,8).

Method Validation

Validation of method performance is important in all sampling and analysis programs but is of special significance for trace organic monitoring because of the large number of compounds of interest and variables affecting method performance. In many situations time, cost, or technical limitations will preclude rigorous method validation and certain assumptions will be required. Ideally any such assumptions will be based on sound technical judgement and/or prior experience.

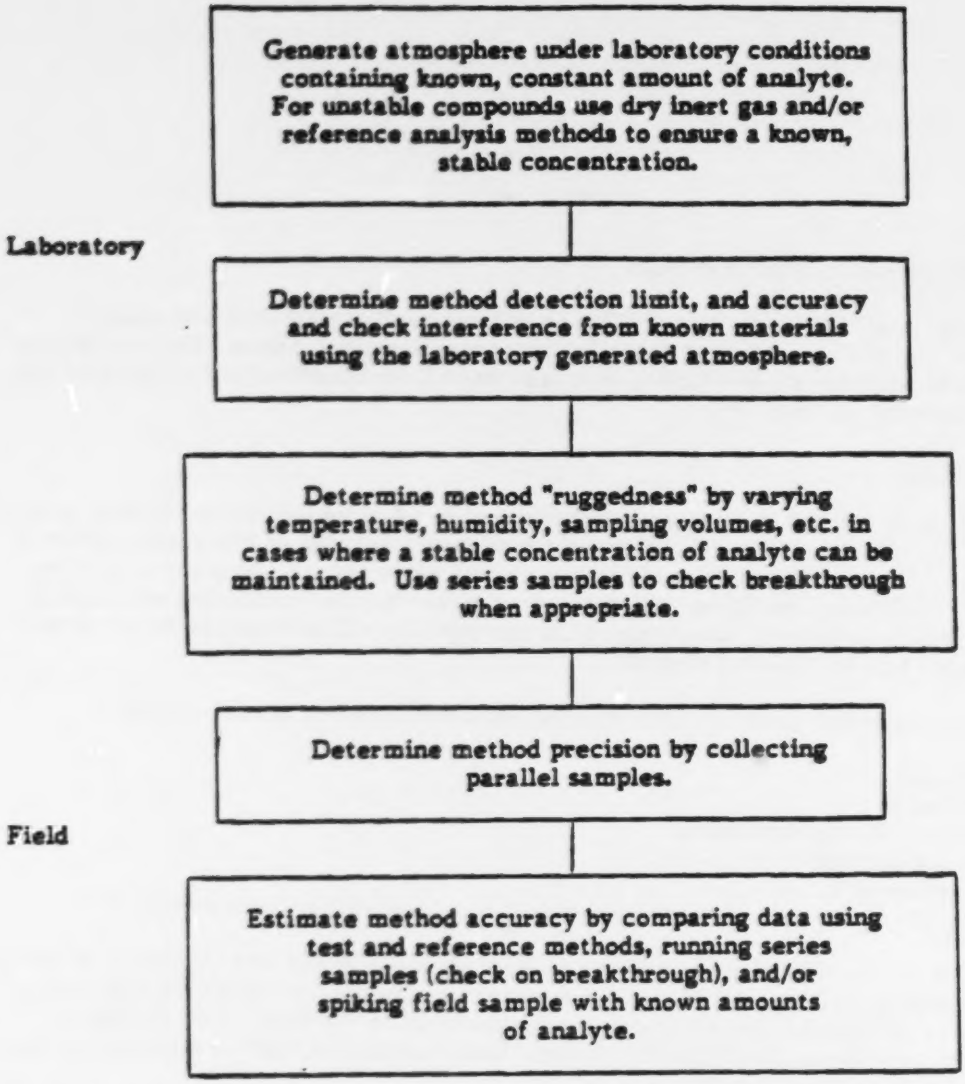
Aspects of method performance requiring validation include the following:

- Accuracy
- Precision
- Blank or background level
- Detection limit
- Interferences
- Ruggedness (effect of important variables on method performance).

In the ideal situation each of these aspects of method performance will be evaluated using the entire sampling and analysis scheme to monitor an atmosphere containing constant, known amounts of the analytes under conditions identical to the field. Two technical limitations prevent the accomplishment of this "ideal" method validation strategy in most cases.

The most severe limitation is that duplication of field conditions is impossible because of the wide variability in field conditions. The second limitation is that generating atmospheres of known constant composition is relatively difficult, especially for unstable components which also pose the greatest problem for sampling and analysis.

A typical approach used to partially overcome these limitations is shown in Figure 12. In this scheme a laboratory validation effort is conducted wherein the emphasis is



Generate atmosphere under laboratory conditions containing known, constant amount of analyte. For unstable compounds use dry inert gas and/or reference analysis methods to ensure a known, stable concentration.

Determine method detection limit, and accuracy and check interference from known materials using the laboratory generated atmosphere.

Determine method "ruggedness" by varying temperature, humidity, sampling volumes, etc. in cases where a stable concentration of analyte can be maintained. Use series samples to check breakthrough when appropriate.

Determine method precision by collecting parallel samples.

Estimate method accuracy by comparing data using test and reference methods, running series samples (check on breakthrough), and/or spiking field sample with known amounts of analyte.

Figure 12. Method Validation Scheme

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placed on generating a known, stable concentration of analyte. Unstable compounds may require the use of dry, inert gas (e.g., nitrogen) to make up the atmosphere. In some cases reference methods may be available as a check on compound stability (such methods need not be highly specific since a relatively clean atmosphere is being employed).

Method detection limit, precision, accuracy, interferences, and background can be determined using the laboratory generated atmosphere. Method ruggedness can be tested provided the variables do not affect the analyte stability; unstable compounds often will not meet this requirement.

The field method validation efforts include a check on precision using parallel sampling. Accuracy can be estimated through the use of reference or alternate methods, and/or spiking field samples with known quantities of analyte. The latter approach must be accomplished in such a manner that all of the spiked material enters the sampling device. Alternatively, one can choose to spike the collected sample (e.g., impinger liquid, resin cartridge, etc.) as a check only on the sample transport and analytical procedures. Series samplers can be used as a check on capture efficiency (analyte breakthrough) but will not determine accuracy. In many cases, it will be useful to collect series samples using various sampling volumes to further document component breakthrough characteristics.

Instrument Calibration

Instrument calibration requirements for sampling and analysis equipment are outlined in Table 19. Specific calibration and maintenance procedures will vary somewhat from one manufacturer to another, hence the user should consult the instrument manual for more specific information.

Sampling equipment calibration procedures for toxic organic monitoring are similar to other types of monitoring and adequate information on this subject can be found in the literature(59). Continuous analyzers require that a suitable calibration standard be available in the field. Ideally the calibration standard is a dilute mixture or series of dilute mixtures of the analyte at stable concentrations. Methods for generating such atmospheres can be static (e.g., dilution flasks, compressed gas cylinders) or dynamic (e.g., permeation tubes, diffusion tubes, syringe delivery systems). In all cases, a method of generating clean air must be available in order to set the baseline level on the continuous monitor as well as for the generation of calibration standards. Methods for generating clean air as well as static and dynamic calibration methods are discussed in the literature(4).

In general, static systems are most convenient to use and are the preferrred calibration methods, provided the analytes are stable in the dilution system. Generally light hydrocarbons and other stable, volatile compounds (e.g., halocarbons) are suitable for static calibration. Dynamic calibration systems, while more complex for field use, are often required for reactive materials (e.g, phosgene) which may be degraded in the static systems.

Less volatile materials such as PCBs, organochlorine, pesticides, or PAHs are rarely of interest for continuous monitors since the ambient concentrations of these materials are usually not detectable using this approach. If atmospheres of such compounds are to be generated probably the best approach is a heated dynamic dilution system wherein a dilute solution of the material in a volatile solvent is delivered at a constant rate into the gas stream using a syringe pump.

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TABLE 19. CALIBRATION REQUIREMENTS FOR SAMPLING AND ANALYSIS INSTRUMENTATION

Device	Parameter Calibrated	Method of Calibration	Approximate Frequency	Comments
Sampling Instrumentation				
Sampling pump and controller	Flow rate	Wet or dry test meter or calibrated rotometer	Weekly	
Sample volume measurement device (usually a dry test meter)	Total volume	Wet test meter	Weekly	Must be determined at known atmospheric pressure and temperature. Flow rate should be similar to that used for sampling.
Analytical Instruments				
Continuous monitors (e.g., FID, PID, FPD, etc.)	Response	Generation of test atmosphere of known concentration	Daily or more frequently if required	Test atmosphere should be referenced to a primary standard (e.g., NBS benzene in air). Flow/pressure conditions should duplicate sampling process.
Chromatographic instruments	Column performance and retention time for each analyte	Injection of standard using the same process as for sample injection	Daily or more frequently if required	Standard composition should be checked against primary standards if available.
Chromatographic instruments	Response for each analyte	Same as above	Same as above	Same as above
GC/MS	Response and retention time for each analyte	Same as for other chromatographic instruments.		
GC/MS	Mass spectral resolution and turning parameters	(a) Introduction of perfluoro-compound directly into MS (b) Injection of tuning standard (e.g., bromofluorobenzene) into GC	Daily	Selection of tuning standards will be dependent on type of of analysis being performed.

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Chromatographic instrumentation requires calibration of both the retention time and response characteristics of the analytes under the conditions used for the analysis of samples. Samples delivered to the instrument in liquid form (e.g., XAD or PUF extracts, impingers, etc). represent no particular problems since liquid standards of the analytes may be readily prepared. However, techniques such as whole air injection, cryogenic trapping, and thermal desorption (e.g., Tenax) require the generation of a known, stable gas phase calibration standard, using methods similar to those described for continuous monitors. In the case of the Tenax thermal desorption method standards have been successfully prepared using a heated static dilution flask wherein the sample is injected onto a clean Tenax cartridge using a gas-tight syringe.

The performance of GC columns, especially capillary columns should be checked periodically in terms of column efficiency (theoretical plates) and peak asymmetry (especially for polar compounds). This performance check can be done using liquid calibration standards and is a useful tool for determining when a column needs to be replaced.

Mass spectrometers require various calibration steps, in addition to the normal chromatographic calibration requirements. These include calibration of the mass spectral relative intensities and mass resolution. Quadrupole MS systems are greatly effected by such tuning parameters and hence data performance checks are required to ensure the usefulness of the mass spectrum for peak identification.

In practice, two levels of MS tuning calibration are usually performed. First a volatile perfluoro-compound (e.g., perfluorokerosine or perfluorotributylamine) is introduced into the ion source and the MS tuning parameters are adjusted to yield certain spectral characteristics. This tuning process is usually described in detail in the instrument manual. A second level of tuning involves the injection of a particular compound EPA methodology (70) prescribes bromofluorobenzene for volatiles and decafluorotriphenylphosphine (DFTPP) for semivolatile compounds onto the GC/MS system. If the mass spectral characteristics for the reference compound are not correct, the parameters are adjusted and the calibration process repeated.

Routine Quality Control

In addition to method validation and instrument calibration processes, the monitoring program should include certain processes for periodically documenting performance of the sampling and analysis procedures. Typical frequencies for sampling/analysis QC samples are shown in Table 20. In the case of continuous monitors the calibration process itself serves as a periodic indicator of method performance. Other sampling and analysis systems require the collection or acquisition of QC samples to check method performance. The types of QC samples of primary value include:

- Blanks (both field and laboratory)
- Spiked samples
- Internal standards
- Replicate parallel samples (or split samples)
- Series samples
- Reference samples.

Blanks should be processed exactly as the samples, except that no air is drawn through the sampler. If samples are transported to the laboratory for analysis then laboratory as well as field blanks should be included. In the case of resin samples (e.g., Tenax)

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Table 20. Typical Sampling/Analysis Frequencies for QC Samples

Type of Sample	Typical Frequency
Field Blanks	Each Sample Set; at least 10% of total number of samples.
Laboratory Blanks	Daily; at least 10% of total number of samples. Each batch of samples.
Spiked Samples	Each sample set; weekly
Duplicate (parallel) Samples	10% of total number of samples; each sample set.
Instrument Calibration Standards	Daily
Reference Samples	Weekly
Series (Backup) Samples	Each sample set.

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both laboratory and field blanks should be routinely analyzed since contamination during transport is a common problem. Material blanks such as Tenax cartridges, impinger solutions, etc. should be routinely analyzed prior to sampling to avoid wasting valuable field efforts due to contamination. Blanks for whole air collection or cryogenic trapping systems will simply be clean air as used for instrument calibration.

Spiked samples must be prepared in such a manner that (a) the sample form is not altered by the spiking process and (b) all of the spike material is available to the sampling system. In many cases, the air stream itself cannot be spiked because of technical practicalities. Consequently the most common approach is to spike the collection matrix (e.g., Tenax resin, impinger, etc.) either before or after sampling. Resin cartridges can be spiked using the static dilution system described above. In some cases (e.g., for volatile, stable compounds) a whole air sample can be collected in a cylinder or Teflon bag and spiked with a known amount of analyte.

The use of internal standards (IS) is advisable for chromatographic methods for which the IS can be placed into the sample without altering it. The use of an IS helps to track instrument sensitivity and to compensate for losses during sample processing. Internal standards are most commonly employed for liquid injection or thermal desorption methods but are not advisable for whole air injection or cryogenic trapping in most cases. Internal standards are especially useful for GC/MS techniques since the stable isotopically (e.g., deuterium or ^{13}C) labeled analytes can be placed into the sample and compensate for any losses during processing or changes in instrument response. This approach has been used extensively for Tenax thermal desorption procedures.

Method precision can be routinely monitored by collecting replicate parallel samples. The precision of the analytical step alone can be determined using split samples, provided homogeneous splits can be prepared without contaminating or otherwise altering the sample. In practice impinger solutions and other liquid samples can be split, but resin samples cannot due to inhomogeneous distribution of the analytes in the resin.

Collection of replicate samples of varying sample volumes can be useful for determining sampling volume effects on the method. Series samples are recommended as routine checks on breakthrough for resin samplers, since changes in atmospheric conditions may alter the breakthrough characteristics of a given analyte. Collection of series samples using different sample volumes, while time consuming, may be a necessary diagnostic tool in certain cases. This type of consideration is discussed in a recent report for solid adsorbent sampling procedures(60).

Reference samples, especially standards available from NBS, are useful as a routine check on method accuracy although only a limited number of such samples are available. NBS gas standards for organics (e.g., benzene) will become available in the near future and will be of great value in the toxic organic monitoring area. Secondary standards supplied by various manufacturers and calibrated against an NBS reference (e.g., propane in air) are currently in widespread use both of instrument calibration and routine quality control. NBS SRM 1649, an urban dust, is available as a reference standard for particulate phase PAH determinations.

Data Handling

This section of the TAD discusses specific calculation processes for converting raw data to a meaningful form. Methods for data presentation and QA requirements with respect to data processing have been presented in Section 3 and references therein(9).

Most of the NIOSH and ASTM methods contain equations for converting raw analytical data to final concentrations, many of which are applicable to other sampling and analysis methods. Raw data obtained during the sampling and analysis process should include the following:

- Volume of sample collected (uncorrected for ambient pressure and temperature)-V_{SA}
- Temperature of sample volume measuring system-T_S
- Ambient atmospheric pressure at sampling site-P_S
- Quantity of analyte in total sample-Q_A.

In almost all cases, the final data should be presented in terms of quantity of analyte per unit volume, under standard conditions (25 C and 760 mm Hg pressure). Actual sample volume can be converted to standard sample volume V_{SS} using the following equation:

$$V_{SS}\,(\mathrm{m}^3) = V_{SA}\,(\mathrm{m}^3) \times \frac{298}{T_S\,(^\circ\mathrm{C}) + 273} \times \frac{P_S\,(\mathrm{mm\ Hg})}{760}$$

The concentration of analyte (C_A) in the sample under standard conditions can then be readily calculated as follows:

$$C_A\,(\mu\mathrm{g/m}^3) = \frac{Q_A\,(\ \mathrm{g})}{V_{SS}\,(\mathrm{m}^3)}$$

In many cases, one may wish to convert concentrations from μg/m^3 to parts per billion (ppbv), although these units are only meaningful if the material is present entirely in the gas phase (i.e., nonvolatile compounds such as PAHs should always be reported in μg/m^3 or similar units). The following equation can be used to convert μg/m^3 to ppbv for gas phase components at 25 C and 760 mm pressure:

$$C_A\,(\mathrm{ppbv}) = C_A\,(\mu\mathrm{g/m}^3) \times \frac{24.4}{MW_A}$$

where MW_A = molecular weight of analyte.

In many cases, hydrocarbon concentrations are most useful when reported in terms of ppbC (parts per billion carbon) since this unit is relatively proportional to the output of an FID detector for such compounds. The following equations can be used to calculate ppbC:

$$C_A\,(\mathrm{ppbC}) = C_A\,(\mathrm{ppbv}) \times N_C$$

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where N_C = the number of carbons in the analyte molecule. In a strict sense the term ppbC should be reserved for hydrocarbons since the presence of O, Cl, N, etc. greatly affects the per carbon response of the FID.

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APPENDIX C
BACKGROUND INFORMATION

APPENDIX C

BACKGROUND INFORMATION

Preparation and implementation of an Air Pathway Analysis (APA) Emergency Field Guide is recommended to support site disturbance activities. For example, excavation during remedial/removal actions can result in an unplanned release of hazardous contaminants to the air pathway. Implementation of a site/source-specific APA Field Guide can provide a real-time capability to provide the following information regarding an unplanned air release event during the remedial/removal activities:

- Identification of the impact area
- Estimation of arrival time of release at the impact area
- Air concentration predictions for the impact area that can be compared to health and safety action levels, ARARs, and odor thresholds

An APA Field Guide is based on a strategy that involves a systematic combination of modeling and monitoring methods. Procedures for the conduct of emission rate modeling/monitoring for disturbed-site conditions have been provided in Volume III. Procedures for dispersion and air monitoring have been presented in Volume IV, Sections 2 and 3, respectively. The following is an example APA Field Guide.

APPENDIX C - EXAMPLE APA FIELD GUIDE OUTLINE

C.1 Overview
  C.1.1 Objectives
  C.1.2 Site/Source Description
  C.1.3 Air Pathway Analysis Uncertainty

C.2 Air Pathway Analysis Strategy
  C.2.1 Routine Meteorological Monitoring
  C.2.2 Routine Air Monitoring
  C.2.3 Release Assessment Methodology

C.1 OVERVIEW

C.1.1 Objectives

This Field Guide has been prepared to provide a basis for onsite decision-makers to obtain rapid assessments of potential downwind (onsite and offsite) concentrations in the event of nonroutine air emissions during remedial actions. Specific information obtainable by the application of the Field Guide includes an estimate of the impact area and release arrival times at downwind locations of interest, as well as a prediction of air concentration. The Field Guide has been developed for use by onsite health and safety staff. Familiarity with the procedural instructions of this Field Guide will allow an assessment in a matter of minutes.

C.1.2 Site/Source Description

Site X is located on flat terrain in a community that has a mix of small industrial plants and residential housing. The closest resident lives approximately 1 kilometer from the uncontrolled landfill at the site. The primary air emission source during site remediation will be excavation operations; numerous volatile organic compounds (VOCs) will be emitted.

Candidate air emission constituents of concern identified from air pathway analyses (APAs) conducted during the Remedial Investigation/Feasibility Study (RI/FS) include the following VOCs:

- Benzene
- Carbon tetrachloride
- Chloroform
- Ethyl benzene
- Tetrachloroethane
- Tetrachloroethylene

Moist soil conditions are expected to minimize the potential for particulate emissions during excavation operations.

C.1.3 Air Pathway Analysis Uncertainty

Because of monitoring and modeling uncertainties, Field Guide air concentration predictions should be used for decision-making. For this application, the Industrial Source Complex Short-Term (ISCST) dispersion model was used. Portable organic detectors and colorimetric tubes are the primary monitoring methods for this application. Therefore, the combined Uncertainty Factor (UF) of ±5 for Field Guide air concentration predictions has been estimated for continuous releases. A UF of ±10 has been assumed for instantaneous (puff) releases.

The UFs discussed above refer to maximum (i.e., plume centerline) concentrations at downwind locations of interest. However, for real-time applications there is the potential for large wind direction variabilities. Therefore, for this application it has been assumed that the maximum concentrations, as a function of downwind distance, can occur anywhere within the horizontal boundaries of the impact area. The impact area has been conservatively defined as the plume centerline ±3 sigma y (where sigma y is the horizontal dispersion parameter). Typically, concentrations at ±3 sigma y are approximately a factor of 0.05 of plume centerline values.

The application of this Field Guide is intended for releases that can be characterized as neutrally buoyant. Additionally, the modeling approach selected is based on the assumption that chemical or physical removal mechanisms in the atmosphere are negligible.

C.2 AIR PATHWAY ANALYSIS STRATEGY

The APA strategy developed for this Field Guide is illustrated in Figure C-1. Routine onsite meteorological monitoring should be conducted to ensure that input data are available for characterizing dispersion conditions. Routine air monitoring close to the source should be conducted during excavation operations to detect nonroutine air release conditions. If a nonroutine release is detected, then the multistep release assessment methodology presented in this Field Guide should be implemented. This methodology involves plume measurements (horizontal traverse) 10 meters downwind from the source. The maximum concentration detected 10 meters from the source is extrapolated using dilution factors (based on dispersion modeling results) to obtain concentration estimates at downwind locations of interest. Acetate overlays (stability class-specific) are used in conjunction with a site base map to identify potential impact areas.

C.2.1 Routine Meteorological Monitoring

A 10-meter meteorological station should be operated onsite during the site remediation phase. At a minimum, wind speed, wind direction, and sigma theta should be measured. Sigma theta is the standard deviation of horizontal wind direction; it is used as an indicator of atmospheric stability. The averaging time for the measurements should be 15 minutes. An onsite data logger is planned to facilitate obtaining 15-minute averaged meteorological data automatically.

C.2.2 Routine Air Monitoring

Routine air monitoring during the remedial action phase will be limited to near-source measurements using portable organic detectors and compound-specific colorimetric tubes. As warranted, additional downwind sampling will also be implemented. An onsite gas chromatograph will also be available to conduct confirmatory compound-specific analyses.

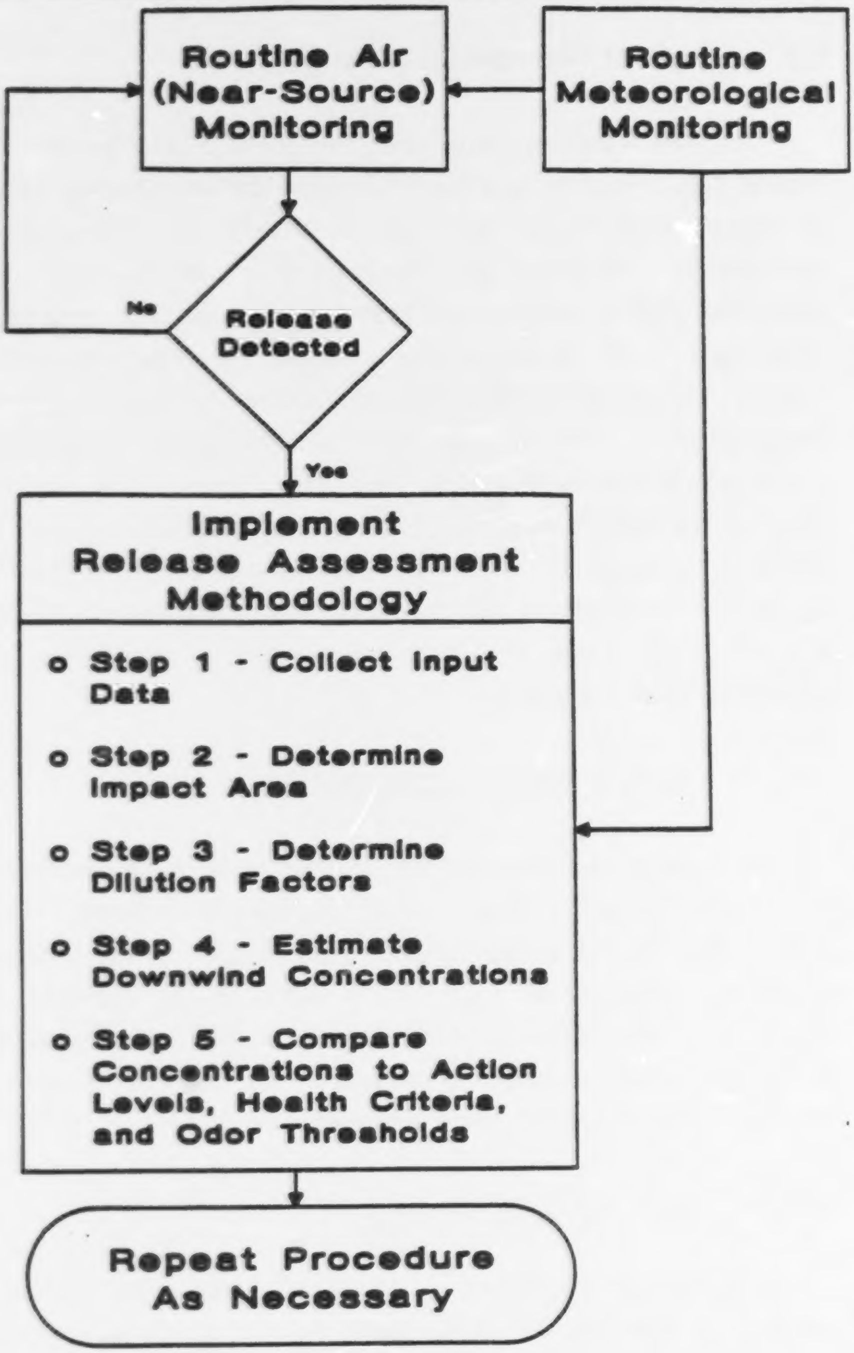

Routine Air (Near-Source) Monitoring
Routine Meteorological Monitoring
No
Release Detected
Yes
Implement Release Assessment Methodology
o Step 1 - Collect Input Data
o Step 2 - Determine Impact Area
o Step 3 - Determine Dilution Factors
o Step 4 - Estimate Downwind Concentrations
o Step 5 - Compare Concentrations to Action Levels, Health Criteria, and Odor Thresholds
Repeat Procedure As Necessary

Figure C-1. APA Emergency Field Guide Strategy - Overview.

C.2.3 Release Assessment Methodology

The release assessment methodology presented below should be implemented if a nonroutine air release is detected (via monitoring or visual observation).

Step 1 - Collect Input Data

- Measure maximum air concentrations based on a horizontal traverse of the plume at 10 meters from the downwind edge of the source.
    - Total organic concentrations based on portable detector measurements.
    - Specific organic concentrations based on colorimetric tube samples.
    - Whole air samples subject to onsite gas chromatographic analyses as confirmatory information.
- If air concentration measurements are not available, consider the use of default emission rate scenarios (Table C-1).
- Collect onsite meteorological data using the most recently available 15-minute averages.
    - Wind direction.
    - Wind speed.
    - Atmospheric stability (based on sigma theta classification presented in Table C-2).

TABLE C-1. DEFAULT EMISSION RATE SCENARIOS FOR SITE X

	Typical		Worst Case	
	Emission Rates (μg/sec)	Release Composition (percent)	Emission Rates (μg/sec)	Release Composition (percent)
Continuous Point Source				
Benzene		10		
Carbon tetrachloride		20		
Chloroform		30		
Ethyl Benzene		5		
Tetrachloroethane		15		
Tetrachloroethylene		20		
		100		
Continuous Area Source				
Benzene				
Carbon tetrachloride				
Chloroform				
Ethyl Benzene				
Tetrachloroethane				
Tetrachloroethylene				
Instantaneous Source				
Benzene				
Carbon tetrachloride				
Chloroform				
Ethyl Benzene				
Tetrachloroethane				
Tetrachloroethylene				

TABLE C-2. SIGMA THETA STABILITY CLASSIFICATION

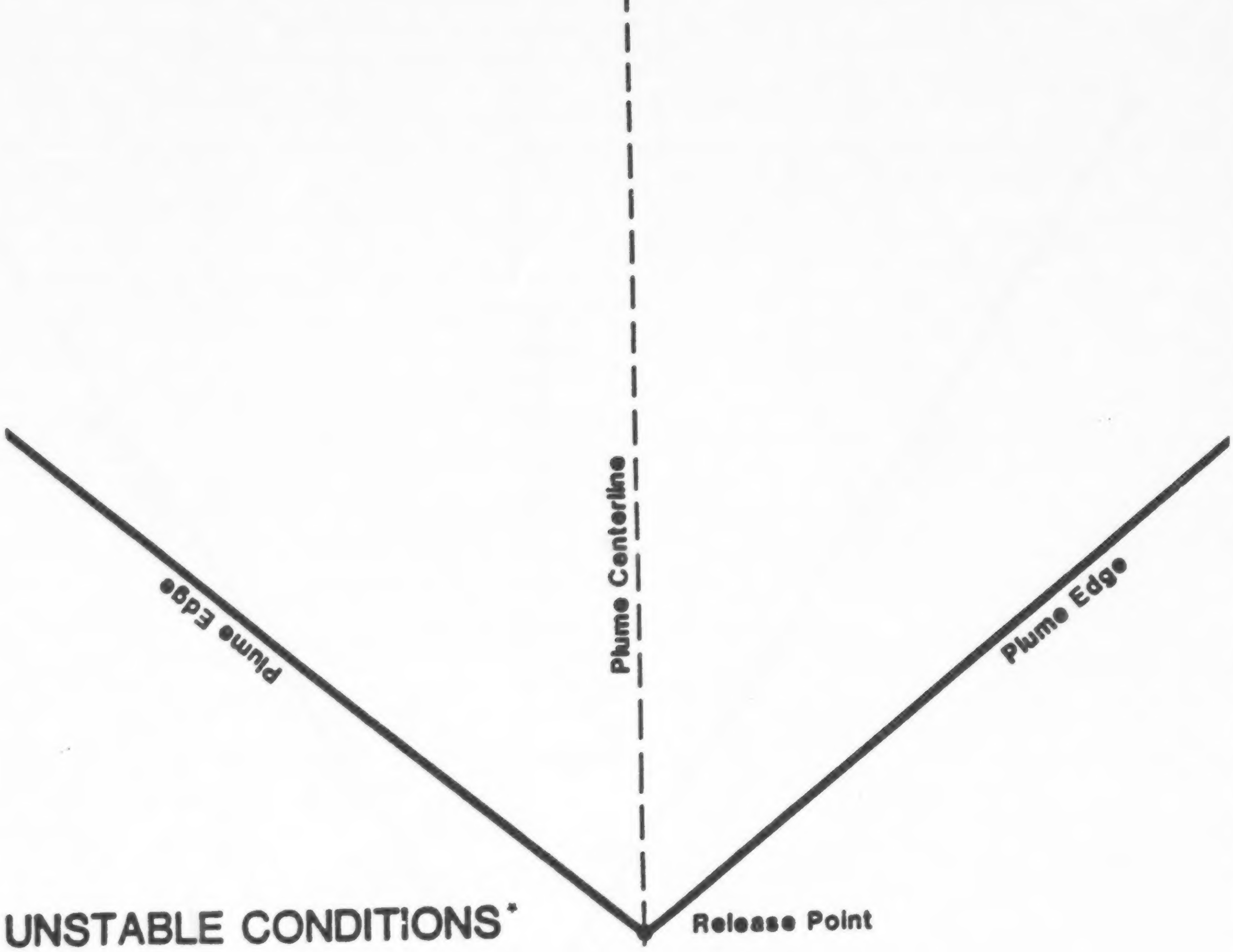
Sigma Theta Value	Classification
Sigma theta greater than or equal to 12.5°	Unstable
Sigma theta greater than or equal to 7.5° but less than 12.5°	Neutral
Sigma theta less than 7.5°	Stable

Step 2 - Determine Impact Area

- Select the appropriate impact area overlay set as follows:
    - Continuous point source (Figures C-2 through C-4).
    - Continuous area source (Figures C-2 through C-4).
    - Instantaneous source (Figures C-5 through C-7).

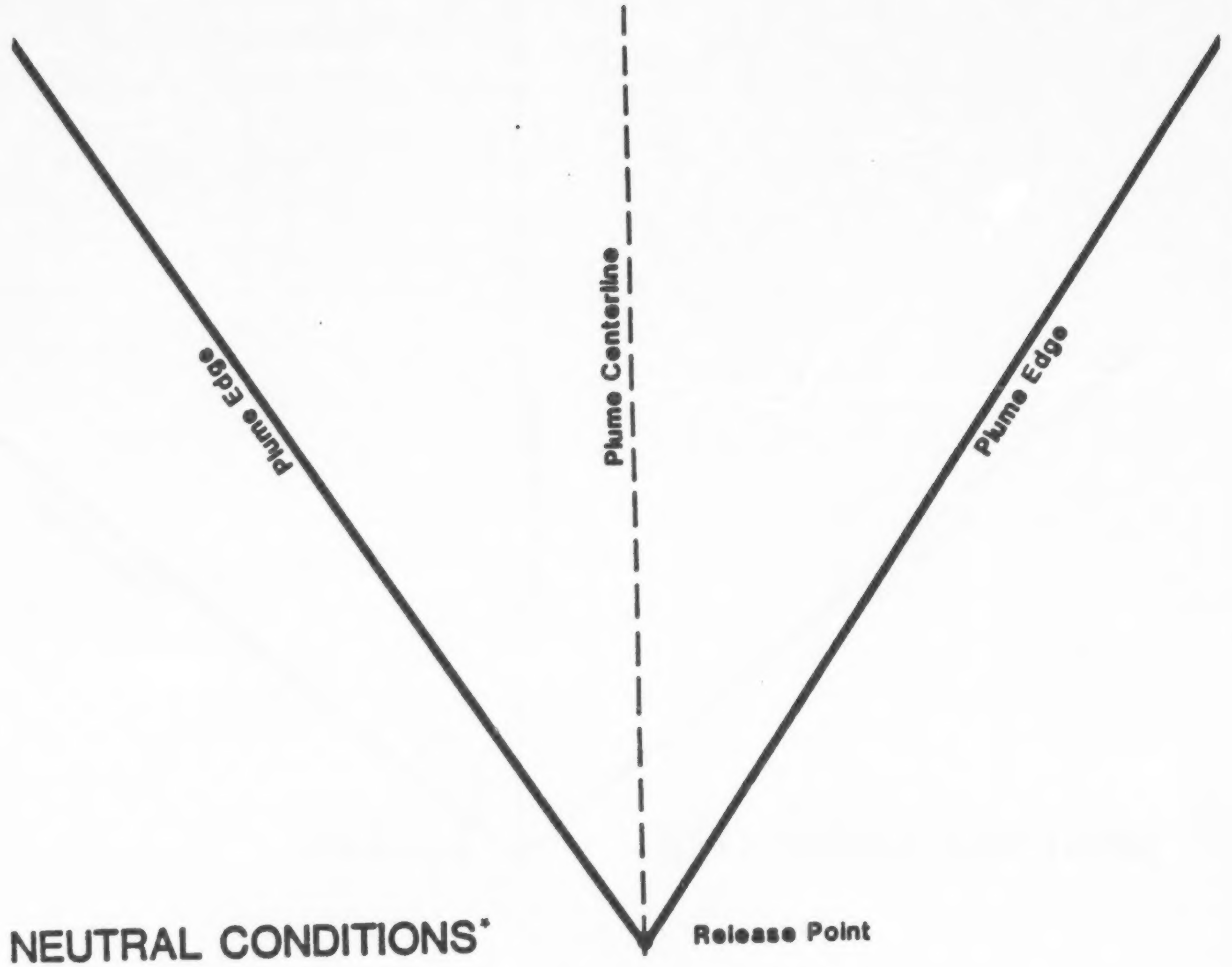
- Select the stability-specific impact area overlay from the appropriate set of figures:
    - Unstable.
    - Neutral.
    - Stable.

- Align the overlay over the base map (Figure C-8) along the direction toward which the wind is flowing. (Wind direction data obtained from the meteorological station will be in terms of direction from which the wind is flowing.) The result should be that the impact area is located downwind of the source, as illustrated in Figure C-9.


Plume Centerline
Plume Edge
Plume Edge
UNSTABLE CONDITIONS*
Release Point

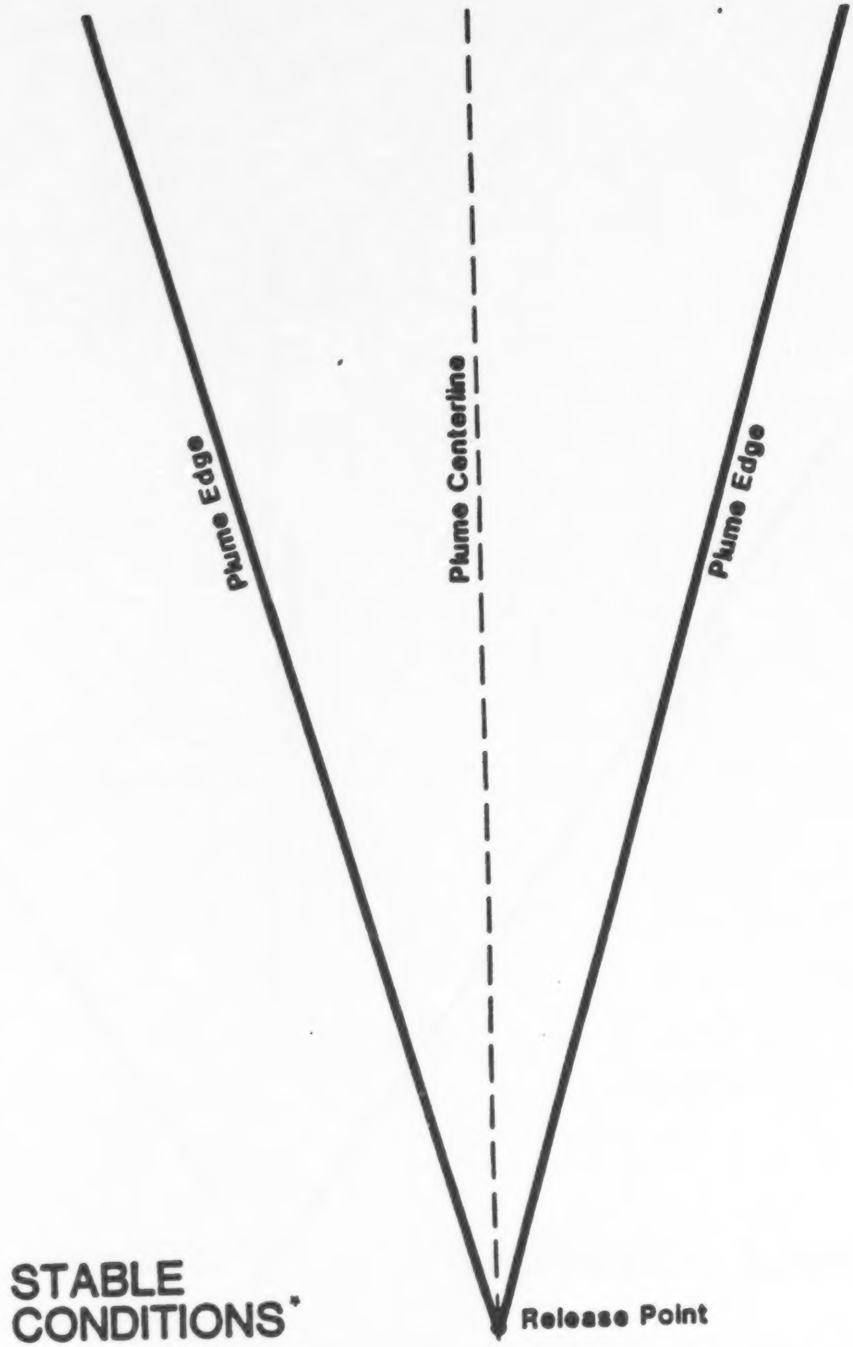
*Example overlay. Do not directly use this overlay for site applications. Site-specific values should be developed for actual calculations.

Figure C-2 Example Impact Area Overlay-Continuous Sources (Unstable Conditions)


Plume Edge
Plume Centerline
Plume Edge
NEUTRAL CONDITIONS*
Release Point

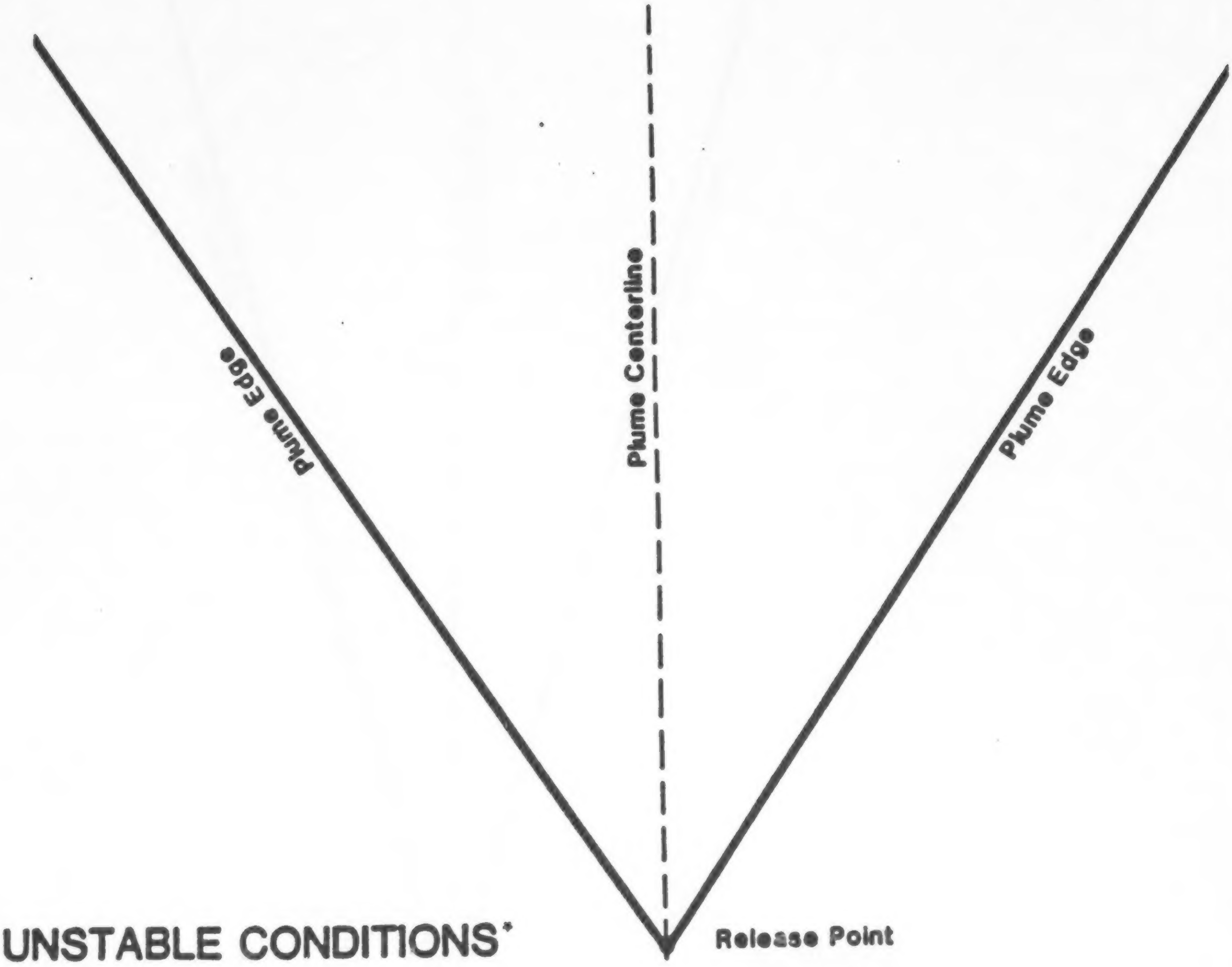
*Example overlay. Do not directly use this overlay for site applications. Site-specific values should be developed for actual applications.

Figure C-3 Example Impact Area Overlay-Continuous Sources (Neutral Conditions)


Plume Edge
Plume Centerline
Plume Edge
STABLE CONDITIONS*
Release Point

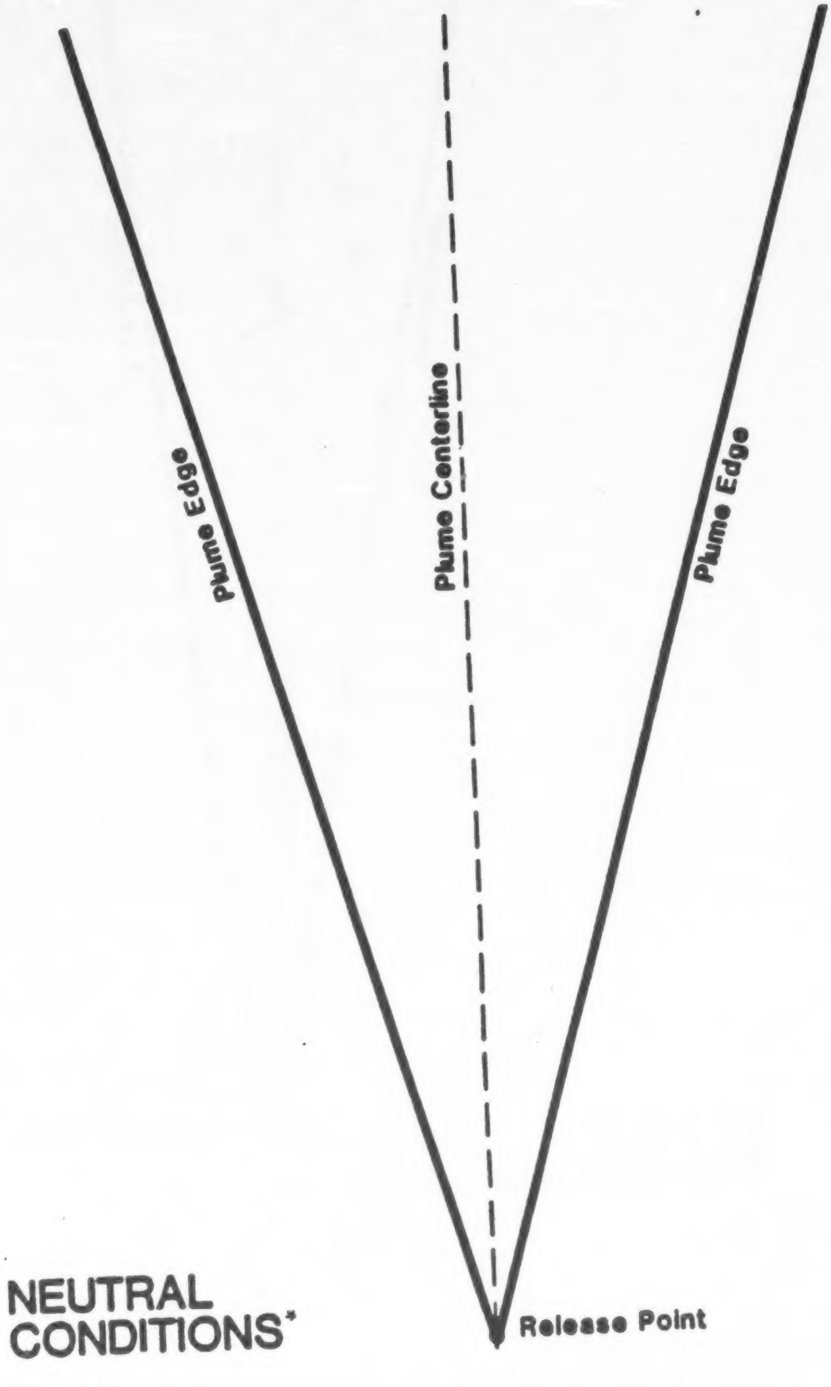
*Example overlay. Do not directly use this overlay for site applications. Site-specific values should be developed for actual applications.

Figure C-4 Example Impact Area Overlay-Continuous Sources (Stable Conditions)


Plume Edge
Plume Centerline
Plume Edge
UNSTABLE CONDITIONS*
Release Point

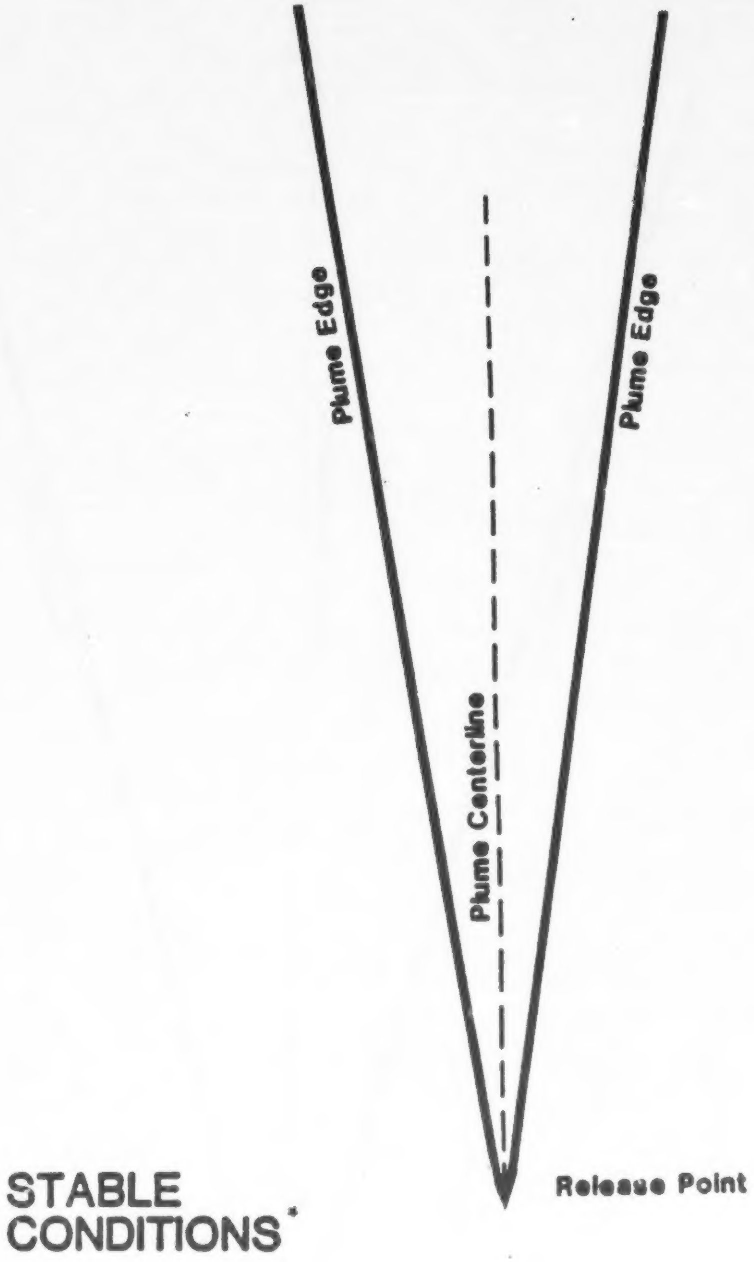
*Example overlay. Do not directly use this overlay for site applications. Site-specific values should be developed for actual applications.

Figure C-5 Example Impact Area Overlay - Instantaneous Sources (Unstable Conditions)


Plume Edge
Plume Centerline
Plume Edge
NEUTRAL CONDITIONS*
Release Point

*Example overlay. Do not directly use this overlay for site applications. Site-specific values should be developed for actual applications.

Figure C-6 Example Impact Area Overlays - Instantaneous Sources (Neutral Conditions)


Plume Edge
Plume Centerline
Plume Edge
STABLE CONDITIONS*
Release Point

*Example overlay. Do not directly use this overlay for site applications. Site-specific values should be developed for actual applications.

Figure C-7 Example Impact Area Overlays - Instantaneous Sources (Stable Conditions)

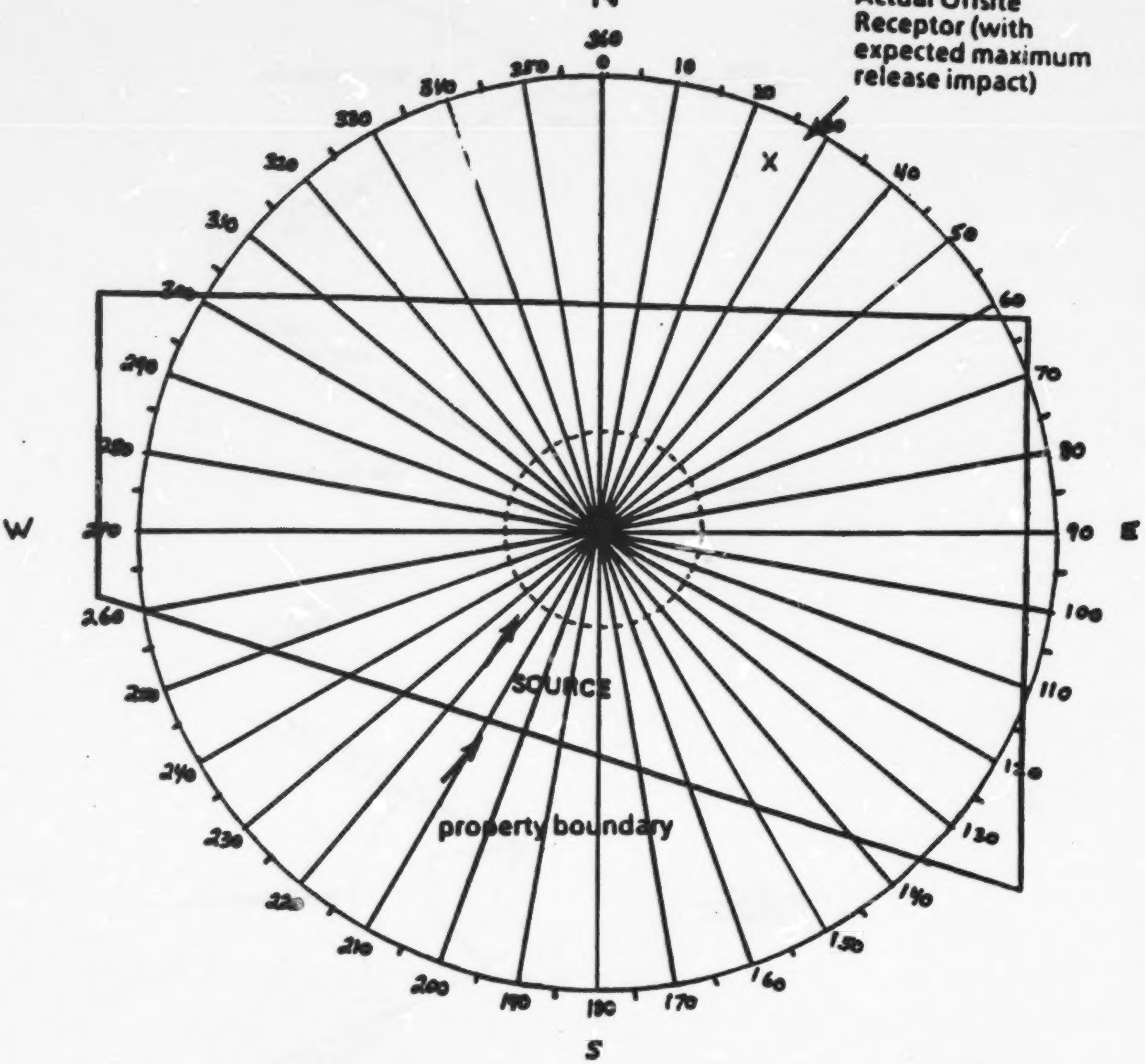

N
Actual Offsite
Receptor (with
expected maximum
release impact)
360
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
190
200
210
220
230
240
250
260
270
280
290
300
310
320
330
340
350
X
W
E
S
SOURCE
property boundary

Figure C-8 Example Base Map - Site X

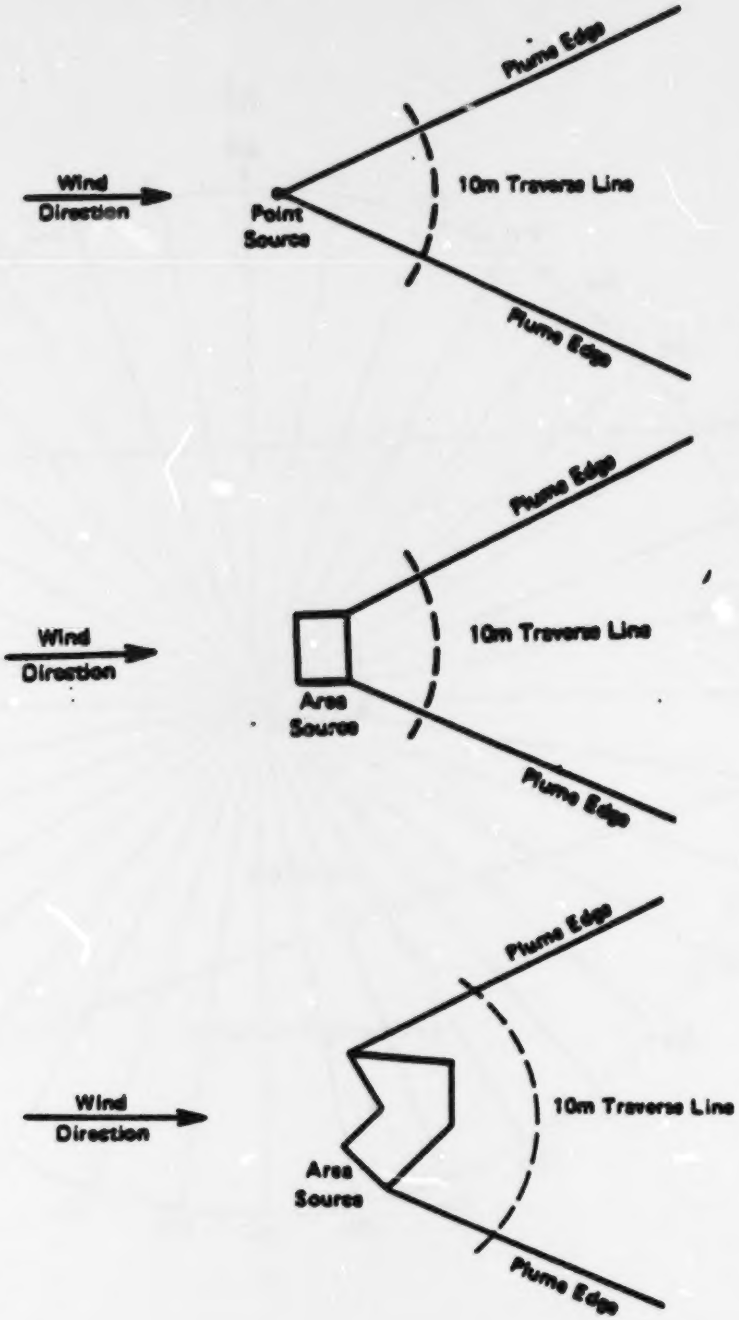

Plume Edge
Wind
Direction
Point
Source
10m Traverse Line
Plume Edge
Plume Edge
Wind
Direction
10m Traverse Line
Area
Source
Plume Edge
Plume Edge
Wind
Direction
10m Traverse Line
Area
Source
Plume Edge

Figure C-9 Example Impact Area Overlay Alignment Relative to Wind Direction and Source

Step 3 - Determine Dilution Factors

- Select the appropriate dilution factor table as follows:
  - Continuous point source (Table C-3).
  - Continuous area source.

    Unstable (Table C-4).
    Neutral (Table C-5).
    Stable (Table C-6).
  - Instantaneous source (Table C-7).
- Select the stability-specific dilution factor for downwind distance(s) of interest (use the appropriate column based on source size for area/volume sources).

TABLE C-3. EXAMPLE DILUTION FACTORS - POINT-SOURCE RELEASE

Downwind Distance (km)	Dilution Factor (dimensionless)		
	Unstable*	Neutral*	Stable*
0.1	1.3×10^{-2}	1.1×10^{-2}	9.4×10^{-3}
0.5	6.1×10^{-4}	6.3×10^{-4}	5.2×10^{-4}
1.0	1.7×10^{-4}	2.0×10^{-4}	1.7×10^{-4}
1.5	8.5×10^{-5}	1.0×10^{-4}	9.2×10^{-5}
2.0	5.2×10^{-5}	6.5×10^{-5}	6.0×10^{-5}
2.5	3.5×10^{-5}	4.6×10^{-5}	4.4×10^{-5}
3.0	2.6×10^{-5}	3.5×10^{-5}	3.4×10^{-5}
3.5	2.0×10^{-5}	2.8×10^{-5}	2.7×10^{-5}
4.0	1.6×10^{-5}	2.3×10^{-5}	2.3×10^{-5}
4.5	1.3×10^{-5}	1.9×10^{-5}	1.9×10^{-5}
5.0	1.1×10^{-5}	1.6×10^{-5}	1.7×10^{-5}
5.5	9.4×10^{-6}	1.4×10^{-5}	1.5×10^{-5}
6.0	8.1×10^{-6}	1.2×10^{-5}	1.3×10^{-5}
6.5	7.1×10^{-6}	1.1×10^{-5}	1.2×10^{-5}
7.0	6.3×10^{-6}	9.9×10^{-6}	1.1×10^{-6}
7.5	5.6×10^{-6}	8.9×10^{-6}	9.9×10^{-5}
8.0	5.1×10^{-6}	8.1×10^{-6}	9.2×10^{-6}
8.5	4.6×10^{-6}	7.4×10^{-6}	8.5×10^{-5}
9.0	4.2×10^{-6}	6.9×10^{-6}	7.9×10^{-6}
9.5	3.9×10^{-6}	6.4×10^{-6}	7.4×10^{-5}
10.0	3.6×10^{-6}	5.9×10^{-6}	6.9×10^{-6}
10.5	3.3×10^{-6}	5.4×10^{-6}	6.5×10^{-5}
11.0	3.0×10^{-6}	5.2×10^{-6}	6.2×10^{-6}
11.5	2.8×10^{-6}	4.8×10^{-6}	5.8×10^{-5}

*Atmospheric stability condition as determined from sigma theta reading

Example values. Do not directly use these values for site applications. Site-specific values should be developed for actual applications.

TABLE C-4. EXAMPLE DILUTION FACTORS (DIMENSIONLESS) - CONTINUOUS AREA SOURCE (UNSTABLE CONDITIONS) *

Downwind Distance (km)	Source Area (Acres)			
	0.5	1.0	2.0	5.0
0.1	4.0×10^{-1}	6.7×10^{-1}	6.7×10^{-1}	6.7×10^{-1}
0.5	6.7×10^{-2}	1.0×10^{-1}	2.0×10^{-1}	4.0×10^{-1}
1.0	2.0×10^{-2}	4.0×10^{-2}	6.7×10^{-2}	2.0×10^{-1}
1.5	1.0×10^{-2}	2.0×10^{-2}	4.0×10^{-2}	6.7×10^{-2}
2.0	6.7×10^{-3}	1.0×10^{-2}	2.0×10^{-2}	4.0×10^{-2}
2.5	4.0×10^{-3}	6.7×10^{-3}	2.0×10^{-2}	4.0×10^{-2}
3.0	4.0×10^{-3}	6.7×10^{-3}	1.0×10^{-2}	2.0×10^{-2}
3.5	2.0×10^{-3}	4.0×10^{-3}	6.7×10^{-3}	2.0×10^{-2}
4.0	2.0×10^{-3}	4.0×10^{-3}	6.7×10^{-3}	2.0×10^{-2}
4.5	2.0×10^{-3}	4.0×10^{-3}	4.0×10^{-3}	1.0×10^{-2}
5.0	2.0×10^{-3}	2.0×10^{-3}	4.0×10^{-3}	1.0×10^{-2}
5.5	1.0×10^{-3}	2.0×10^{-3}	4.0×10^{-3}	6.7×10^{-3}
6.0	1.0×10^{-3}	2.0×10^{-3}	4.0×10^{-3}	6.7×10^{-3}
6.5	6.7×10^{-4}	2.0×10^{-3}	4.0×10^{-3}	6.7×10^{-3}
7.0	6.7×10^{-4}	2.0×10^{-3}	2.0×10^{-3}	6.7×10^{-3}
7.5	6.7×10^{-4}	1.0×10^{-3}	2.0×10^{-3}	4.0×10^{-3}
8.0	6.7×10^{-4}	1.0×10^{-3}	2.0×10^{-3}	4.0×10^{-3}
8.5	4.0×10^{-4}	1.0×10^{-3}	2.0×10^{-3}	2.0×10^{-3}
9.0	4.0×10^{-4}	1.0×10^{-3}	2.0×10^{-3}	4.0×10^{-3}
9.5	4.0×10^{-4}	6.7×10^{-4}	2.0×10^{-3}	4.0×10^{-3}
10.0 - 11.5	4.0×10^{-4}	6.7×10^{-4}	1.0×10^{-3}	4.0×10^{-3}

* Example values. Do not directly use these values for site applications. Site-specific values should be developed for actual applications.

TABLE C-5. EXAMPLE DILUTION FACTORS (DIMENSIONLESS) - CONTINUOUS AREA SOURCE (NEUTRAL CONDITIONS) *

Downwind Distance (km)	Source Area (Acres)			
	0.5	1.0	2.0	5.0
0.1	4.0×10^{-1}	6.7×10^{-1}	6.7×10^{-1}	6.7×10^{-1}
0.5	6.7×10^{-2}	1.0×10^{-1}	2.0×10^{-1}	4.0×10^{-1}
1.0	4.0×10^{-2}	4.0×10^{-2}	6.7×10^{-2}	2.0×10^{-1}
1.5	2.0×10^{-2}	2.0×10^{-2}	4.0×10^{-2}	1.0×10^{-1}
2.0	1.0×10^{-2}	2.0×10^{-2}	4.0×10^{-2}	6.7×10^{-2}
2.5	6.7×10^{-3}	1.0×10^{-2}	2.0×10^{-2}	4.0×10^{-2}
3.0	6.7×10^{-3}	1.0×10^{-2}	2.0×10^{-2}	4.0×10^{-2}
3.5	4.0×10^{-3}	6.7×10^{-3}	2.0×10^{-2}	4.0×10^{-2}
4.0	4.0×10^{-3}	6.7×10^{-3}	1.0×10^{-2}	2.0×10^{-2}
4.5	4.0×10^{-3}	4.0×10^{-3}	1.0×10^{-2}	2.0×10^{-2}
5.0	2.0×10^{-3}	4.0×10^{-3}	6.7×10^{-3}	2.0×10^{-2}
5.5	2.0×10^{-3}	4.0×10^{-3}	6.7×10^{-3}	2.0×10^{-2}
6.0	2.0×10^{-3}	4.0×10^{-3}	6.7×10^{-3}	2.0×10^{-2}
6.5	2.0×10^{-3}	4.0×10^{-3}	6.7×10^{-3}	1.0×10^{-2}
7.0	2.0×10^{-3}	4.0×10^{-3}	4.0×10^{-3}	1.0×10^{-2}
7.5	2.0×10^{-3}	2.0×10^{-3}	4.0×10^{-3}	1.0×10^{-2}
8.0	1.0×10^{-2}	2.0×10^{-3}	4.0×10^{-3}	6.7×10^{-3}
8.5	1.0×10^{-2}	2.0×10^{-3}	4.0×10^{-3}	6.7×10^{-3}
9.0	1.0×10^{-2}	2.0×10^{-3}	4.0×10^{-3}	6.7×10^{-3}
9.5	1.0×10^{-2}	2.0×10^{-3}	4.0×10^{-3}	6.7×10^{-3}
10.0	1.0×10^{-2}	2.0×10^{-3}	4.0×10^{-3}	6.7×10^{-3}
10.5	6.7×10^{-3}	2.0×10^{-3}	4.0×10^{-3}	6.7×10^{-3}
11.0 - 11.5	6.7×10^{-3}	1.0×10^{-2}	2.0×10^{-3}	6.7×10^{-3}

* Example values. Do not directly use these values for site applications. Site-specific values should be developed for actual applications.

TABLE C-6. EXAMPLE AREA SOURCE DILUTION FACTORS (DIMENSIONLESS) - CONTINUOUS (STABLE CONDITIONS) *

Downwind Distance (km)	Source Area (Acres)			
	0.5	1.0	2.0	5.0
0.1	4.0×10^{-1}	6.7×10^{-1}	6.7×10^{-1}	6.7×10^{-1}
0.5	6.7×10^{-2}	2.0×10^{-1}	2.0×10^{-1}	4.0×10^{-1}
1.0	4.0×10^{-2}	6.7×10^{-2}	6.7×10^{-2}	2.0×10^{-1}
1.5	2.0×10^{-2}	4.0×10^{-2}	4.0×10^{-2}	1.0×10^{-1}
2.0	1.0×10^{-2}	2.0×10^{-2}	4.0×10^{-2}	6.7×10^{-2}
2.5	6.7×10^{-3}	2.0×10^{-2}	2.0×10^{-2}	4.0×10^{-2}
3.0	6.7×10^{-3}	1.0×10^{-2}	2.0×10^{-2}	4.0×10^{-2}
3.5	4.0×10^{-3}	1.0×10^{-3}	2.0×10^{-2}	4.0×10^{-2}
4.0	4.0×10^{-3}	6.7×10^{-3}	1.0×10^{-2}	4.0×10^{-2}
4.5	4.0×10^{-3}	6.7×10^{-3}	1.0×10^{-2}	2.0×10^{-2}
5.0	4.0×10^{-3}	6.7×10^{-3}	1.0×10^{-3}	2.0×10^{-2}
5.5	2.0×10^{-3}	4.0×10^{-3}	6.7×10^{-3}	2.0×10^{-2}
6.0	2.0×10^{-3}	4.0×10^{-3}	6.7×10^{-3}	2.0×10^{-2}
6.5	2.0×10^{-3}	4.0×10^{-3}	6.7×10^{-3}	2.0×10^{-2}
7.0	2.0×10^{-3}	4.0×10^{-3}	6.7×10^{-3}	1.0×10^{-2}
7.5	2.0×10^{-3}	4.0×10^{-3}	6.7×10^{-3}	1.0×10^{-2}
8.0	2.0×10^{-3}	4.0×10^{-3}	4.0×10^{-3}	1.0×10^{-3}
8.5	2.0×10^{-3}	2.0×10^{-3}	4.0×10^{-3}	1.0×10^{-3}
9.0	2.0×10^{-3}	2.0×10^{-3}	4.0×10^{-3}	1.0×10^{-3}
9.5	1.0×10^{-3}	2.0×10^{-3}	4.0×10^{-3}	1.0×10^{-3}
10.0 - 11.5	1.0×10^{-3}	2.0×10^{-3}	4.0×10^{-3}	6.7×10^{-3}

* Example values. Do not directly use these values for site applications. Site-specific values should be developed for actual applications.

TABLE C-7. EXAMPLE DILUTION FACTORS - INSTANTANEOUS RELEASE

Downwind Distance (km)	Dilution Factor (dimensionless)		
	Unstable*	Neutral*	Stable*
0.1			
0.5			
1.0			
1.5			
2.0			
2.5			
3.0			
3.5			
4.0			
4.5			
5.0			
5.5			
6.0			
6.5			
7.0			
7.5			
8.0			
8.5			
9.0			
9.5			
10.0			
10.5			
11.0			
11.5			

* Site-specific values should be developed.

Step 4 - Estimate Downwind Concentrations

- Use Equation C-1 if the 10-meter downwind concentration has been measured.

$$\text{(Concentration at Distance X)} = \text{(Concentration at 10 m)} \times \text{(Dilution Factor at Distance X)} \qquad \text{(C-1)}$$

- Example:

A release occurs at an excavation pit. The measured peak concentration is 500 parts per million (ppm) at a nominal distance of 10 meters from the source.

According to data from the meteorological tower, the sigma theta value indicates neutral stability.

Using the dilution factor table, neutral stability at 1 kilometer yields a dilution factor of $2.0\text{x}10^{-4}$.

The calculation using the above formula for determining the concentration at 1 kilometer is as follows:

$500 \text{ ppm x } 2.0\text{x}10^{-4} = 1.0\text{x}10^{-1} \text{ ppm}$
$= 0.01 \text{ ppm}$
$=$ 100 parts per billion (ppb)

- Use Equation C-2 to estimate 10-meter concentrations if the default emission rates (Table C-1) or measured emission rates are used to characterize the release (obtain the 10-meter dilution factor values from Table C-8).

TABLE C-8. EXAMPLE DILUTION FACTORS (sec/m^3) AT 10 METERS IF EMISSION RATE DATA ARE AVAILABLE*

	Unstable	Neutral	Stable
Point Source			
Area Source			
0.5 acre			
1.0 acre			
2.0 acres			
5.0 acres			
Instantaneous			

* Site-specific values should be developed.

$$\left(\text{Concentration at 10 m, } \mu g/m^3\right) = \left(\text{Emission Rate, } \mu g/sec\right) \times \left(\text{Dilution Factor at Distance X, } sec/m^3\right) \qquad \text{(C-2)}$$

- Use Equations C-3 and C-4 to convert concentration units, as necessary.

$$\text{Concentration, ppb} = \left(\text{Concentration, } \mu g/m^3\right) \times \frac{24.04}{M} \qquad \text{(C-3)}$$

where

M is the molecular weight of the constituent of interest
ppb is parts per billion by volume at 20°C

$$\text{Concentration, } \mu g/m^3 = \left(\text{Concentration, ppb}\right) \times \frac{M}{24.04} \qquad \text{(C-4)}$$

Step 5 - Compare Concentrations to Action Levels, Health Criteria, and Odor Thresholds

- Compare concentration predictions at downwind distances of interest to the criteria presented in Table C-9.

- If only total organic concentration data are available, these concentrations can be conservatively scaled using the constituent-specific composition values presented in Table C-1.

TABLE C-9. EXAMPLE AIR CRITERIA FOR SITE X *

	Site Health and Safety Plan Action Levels	STEL[a] (15 min)	IDLH[b] (30 min)	State ARAR (1 hr)	PEL[c] (8 hr)	Odor Threshold
Total Organics		--	--	--	--	--
Benzene		25 ppm	10 ppm	0.1 ppm	0.1 ppm	31 ppm
Carbon Tetrachloride		20 ppm	300 ppm	0.05 ppm	10 ppm	725 ppm
Chloroform		50 ppm	1,000 ppm	0.1 ppm	50 ppm	733 ppm
Ethyl Benzene		125 ppm	2,000 ppm	1.0 ppm	100 ppm	--
1,1,2,2-Tetrachloroethane		5 ppm	150 ppm	0.01 ppm	5 ppm	--
Tetrachloroethylene		--	500 ppm	5.0 ppm	100 ppm	4.7 ppm

[a] STEL - Short Term Exposure Limit (ACGIH)
[b] IDLH - Immediately Dangerous to Life or Health (NIOSH/OSHA)
[c] PEL - Permissible Exposure Limit (NIOSH/OSHA)

* Example values. Do not directly use these values for site applications. Site-specific values should be developed for actual applications.

Step 6 - Estimate Plume Travel Times

- Determine the downwind distance from the source to potential receptors of interest.

- Select unit travel time (i.e., for 1 km or 1 mile) from Table C-10.

- Estimate plume travel time based on Equation C-5

$$\text{(Travel Time to Receptor)} = \text{(Receptor Downwind Distance)} \times \text{(Unit Travel Time)} \qquad \text{(Eq. C-5)}$$

TABLE C-10

EXAMPLE PLUME TRAVEL TIME VALUES FOR UNIT (1 KM AND 1 MILE) DISTANCES *

Wind Speed (M/S)	Wind Speed (MPH)	Time to Travel 1 km		Time to Travel 1 Mile	
		Minutes	Seconds	Minutes	Seconds
0.447	1	37.0	2,240	60.0	3,600
0.894	2	18.6	1,120	30.0	1,800
1.341	3	12.4	745	20.0	1,200
1.788	4	9.3	560	15.0	900
2.235	5	7.5	450	12.0	720
2.682	6	6.2	370	10.0	600
3.129	7	5.3	320	8.6	514
3.576	8	4.7	280	7.5	450
4.023	9	4.1	250	6.7	400
4.470	10	3.7	225	6.0	360
4.917	11	3.4	205	5.5	327
5.364	12	3.1	190	5.0	300
5.811	13	2.9	170	4.6	277
6.258	14	2.7	160	4.3	257
6.705	15	2.5	150	4.0	240
7.152	16	2.4	140	3.7	225
7.599	17	2.2	130	3.5	212
8.046	18	2.1	125	3.3	200
8.493	19	2.0	120	3.2	189
8.940	20	1.9	1110	3.0	180

* Example values. Do not directly use these values for site applications. Site-specific values should be developed for actual applications.

Step 7 - Document Assessment/Results

- Document the results using a standard form (Table C-11).

- Repeat the steps if the release continues.

TABLE C-11. EXAMPLE OF APA FIELD GUIDE INFORMATION FORM (page 1 of 4)

A. Date: ______________ Person providing information: _______________

B. Point Source - use Appendix A
Area source - use Appendix B (Circle one)

Area source size: __________ acre(s)

C. OBSERVED DATA Time: ___________________

Maximum concentration at 10 meters from the source ____________ µg/m^3 or ppm

Wind direction* __________________ degrees from true N
Wind speed* _____________________ m/sec
Sigma theta* ____________________ degrees

*15-minute averages unless otherwise noted

D. IMPACTED AREA

Plume direction from the source: ______________ degrees
Overlay used: Unstable Neutral Stable (Circle one)
Impacted receptors of concern (list): _____________ _____________
_____________ _____________

E. DILUTION FACTOR

Unstable Neutral Stable (Circle one)

TABLE C-11 (page 2 of 4)

F. CALCULATE DOWNWIND CONCENTRATION

Distance (km)	Dilution Factor	Maximum Concentration Measured at 10 m (Chi) (μg/m^3 or ppm)	Computed Downwind Concentration (μg/m^3 or ppm)	Air Criteria (μg/m^3)
0.1				
0.5				
1.0				
1.5				
2.0				
2.5				
3.0				
3.5				
4.0				
4.5				
5.0				
5.5				
6.0				
6.5				
7.0				
7.5				
8.0				
8.5				
9.0				
9.5				
10.0				
10.5				
11.0				

TABLE C-11 (page 3 of 4)

G. PLUME TRAVEL TIME

To potentially impacted receptors of concern:

Receptor Distance (Km or Mi)	Travel Time (minutes or seconds)
________	________
________	________
________	________
________	________

H. COMMENTS

I. ADDITIONAL INFORMATION

Spill chemical compound(s)*: ______________________________

____

Spill amount: ________________________ gal. or L

Spill area: ________________________ m^2

*If unknown, indicate the compound used for the Health Criteria Assessment

TABLE C-11 (page 4 of 4)

Concentrations measured at locations other than 10 meters downwind:

Location	Concentration ($\mu g/m^3$ or ppm)
________________	____________
________________	____________
________________	____________
________________	____________

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U.S. Environmental Protection Agency
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